# POWER

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## Testing the Man

(See editorial "*Not Found Wanting in Courage*," on page 653)

# Auxiliary Steam Power Plant for Vancouver Island

By W. L. Kidston

*SYNOPSIS—This steam-turbine-driven auxiliary plant, of 4,000 kw., with an ultimate capacity of 20,000 kw., was put in operation through the failure of a transmission line one-half hour after being declared completed by the contractors. Fuel oil is burned in the boiler furnaces, which are also designed for burning coal. The automatic oil-regulating system is gone into in detail.*

During the years 1910 to 1912, inclusive, the rapid growth of the city of Victoria, with its attendant power requirements, severely taxed the abilities of the Vancouver Island Power Co., one of the subsidiaries of the British Columbia Electric Railway Co., Ltd. It became difficult, even with the rapid development of the company's hydro-electric properties, to properly care for the rapidly growing community.

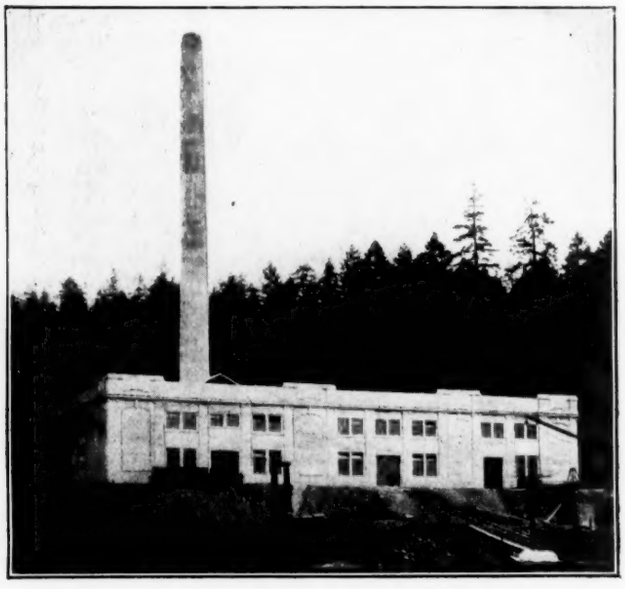

FIG. 1. GENERAL VIEW OF THE POWER PLANT

The British Columbia Electric Railway Co., Ltd., controls the public utilities of Vancouver, New Westminster, Victoria and their immediate vicinities. Its subsidiary company, the Vancouver Island Power Co., has a hydro-electric property in the Jordan River plant, situated about forty miles from Victoria, where it is possible to ultimately develop 36,000 hp. under an effective head of 1150 ft.

A development beyond the installation now in place, however, would require the building of a number of dams in order to supply the required storage reservoirs, and the construction of these dams in time to meet the rapidly growing demands of the community was impossible.

The necessity for the speedy installation of additional capacity and the advisability of putting in a steam auxiliary as a reserve to its system were responsible for the construction of one of the finest steam-turbine plants in the Greater Northwest by the Vancouver Island Power Co.

The company had in operation its hydro-electric plants at Goldstream and at Jordan River. This latter plant was placed in operation in the autumn of 1911, thus increasing the capacity of the system by 8000 kw., but nevertheless the load continued to grow so rapidly that this increase appeared to be inadequate to meet the probable demands of the winter load.

In the limited period available further additions to the hydro-electric plants could not be made, and the installation of the steam auxiliary plant was decided upon. A remarkable coincidence occurred, in that the Jordan River plant had been operating for some two years without a shutdown or failure of the transmission line, and when the first unit of the steam plant was phased out and ready for starting, the failure of the Jordan transmission line compelled the commercial use of the unit within one-half hour after it was pronounced ready for operation.

The contract for the construction of the new steam plant was let to Charles C. Moore & Co. It included the clearing and grading of the site, foundations, building and all machinery with the exception of the steam turbo-generators.

## Turbine Room

The plant, Fig. 1, is situated at Brentwood Bay, on Saanich Inlet, about twelve miles north of Victoria and in proximity to the British Columbia Electric Railway Co.'s interurban railway. The building is of steel-frame construction with reinforced-concrete curtain walls and consists of three bays, 137 ft. long, housing the boilers, turbines and transformers. The bays are 93, 69 and 50 ft. wide respectively. Although the elements of economy and simplicity were given chief consideration, a pleasing architectural appearance has been maintained throughout, and for economic reasons the permanent building has been completed of suitable size to house the ultimate capacity of the plant.

The structural steel for the boiler room is of sufficient strength to support overhead bunkers suspended between the boilers, should it ever be desired to use coal fuel, and the headroom of the boiler room and the location of the columns have been laid out with this in mind.

Near the roof of the building, at such points as to give a maximum of light, windows of liberal size and frequently spaced have been distributed in the curtain walls. The proposed ultimate development of the Brentwood Bay steam plant is 20,000 kw. The preliminary installation consists of two 2000-kw. turbo-generators, as much better delivery can be obtained on units of this size than on those of 5000-kw. capacity. The 2000-kw. units are in the middle of the turbine room, Fig. 2, and can be replaced by 5000-kw. units, if found desirable. They are also located so that if these machines are left in place one 7500-kw. unit can be placed on each side of the existing ones.

The turbines are of the Parsons reaction type with certain modifications, principal among which are the system of balancing, the shroud-ring over the tips of the buckets, the governor and the packing on the low-pressure

end. The generators are three-phase, 60-cycle, 2300-volt, running at 1800 r.p.m.

For excitation purposes, a 75-kw., 125-volt, direct-current generator, directly connected to a simple side-crank, noncondensing automatic engine is provided. The exciter is placed between the main units. One 75-kw., 125-volt, direct-current generator, directly connected to a 110-hp., three-phase, 60-cycle, 2300-volt induction motor, is also provided for excitation and for use at light loads when

One rotative dry-vacuum pump of the crank and flywheel type is furnished with each condenser. These pumps are of the flashport-valve type by which air compressed in the clearance is automatically transferred to the vacuum side of the piston prior to starting the return stroke. This reduces the effective clearance to a minimum and increases the volumetric efficiency to a maximum.

There is also furnished with each condenser, and placed under it, a cast-iron hotwell with a direct connection to a

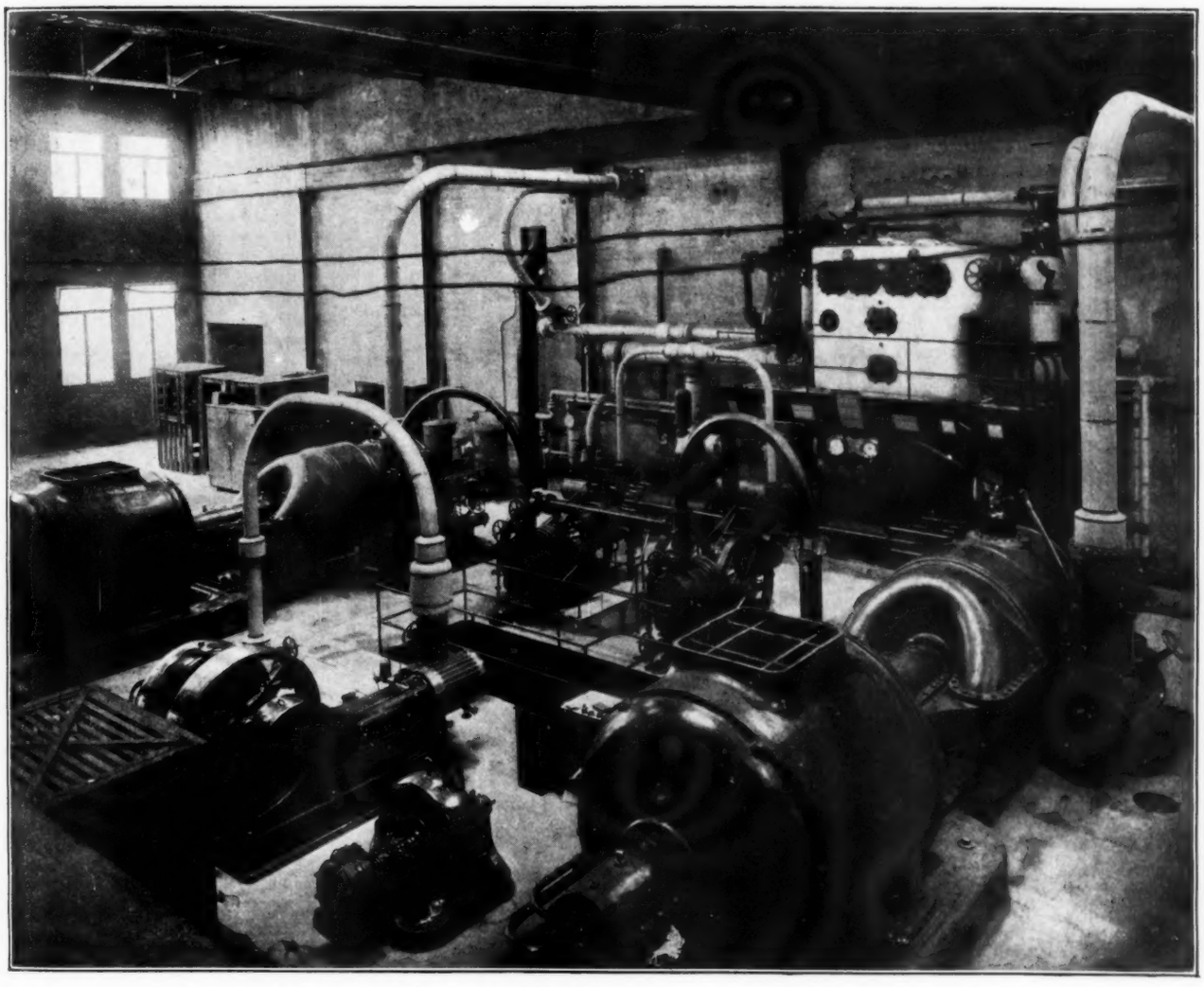

FIG. 2. VIEW OF THE TURBINE ROOM OF THE AUXILIARY STEAM POWER PLANT

the steam-driven unit would cause an excess of auxiliary steam over that required for heating the boiler feed-water supply.

Each turbine exhausts into a surface condenser of the dry-tube type, containing 4000 sq.ft. of cooling surface. The tubes are of brass, ¾ in. in diameter. The dry plates in the condenser drain off the water of condensation as it is formed and allow it to fall to the bottom, where it is withdrawn by the hotwell pump. This arrangement prevents the condensation which takes place in the top part from drowning the lower tubes, thus increasing their rate of conductivity. At the same time, the temperature of condensation is increased, that of the air-pump suction reduced and the quantity of circulating water required is diminished. The low temperature of the air-pump suction decreases the volume of air to be handled, thus reducing the necessary displacement.

2½-in. centrifugal hotwell pump. These pumps are brass fitted, have specially constructed passages to give easy access to the throat of the runner, and each is driven by a 7½-hp. steam turbine at 2400 r.p.m.

Three 14-in. centrifugal circulating pumps are installed. These are brass fitted throughout and two are direct-connected to and driven by steam turbines; the third is motor-driven. Each is of the double-suction balanced type and draws its water from a pump pit below. The water is discharged through individual multiple-disk check valves. Fig. 3 is a plan and elevation of the plant, showing the arrangement of the various units. Two horizontal-duplex, steam-driven boiler-feed pumps are provided. They operate noncondensing, one being of ample capacity for the present plant, the other being a reserve.

One open feed-water heater receives the hotwell-pump discharge and makeup water at the top and distributes it

over iron trays, from which it falls in a finely divided spray. The auxiliary exhaust is passed through this spray, condensing it and at the same time imparting its heat to the feed water. Ample storage space is provided in which to care for the ordinary variation in water level in the heater reservoir due to fluctuation of load. The supply of auxiliary exhaust steam available can be regulated by the use of either steam- or motor-driven circulators, as may be required, so as to obtain a maximum temperature of feed water and at the same time utilize all the auxiliary exhaust without waste.

In laying out the plant it was decided to provide for two rows of boilers with a firing alley between. The present installation consists of six water-tube boilers, Fig. 4, arranged in three batteries. Provision has been made in the building for the installation of ten additional boilers. Each unit consists of 18 sections, each having 12 four-inch tubes 18 ft. long, over which are mounted two

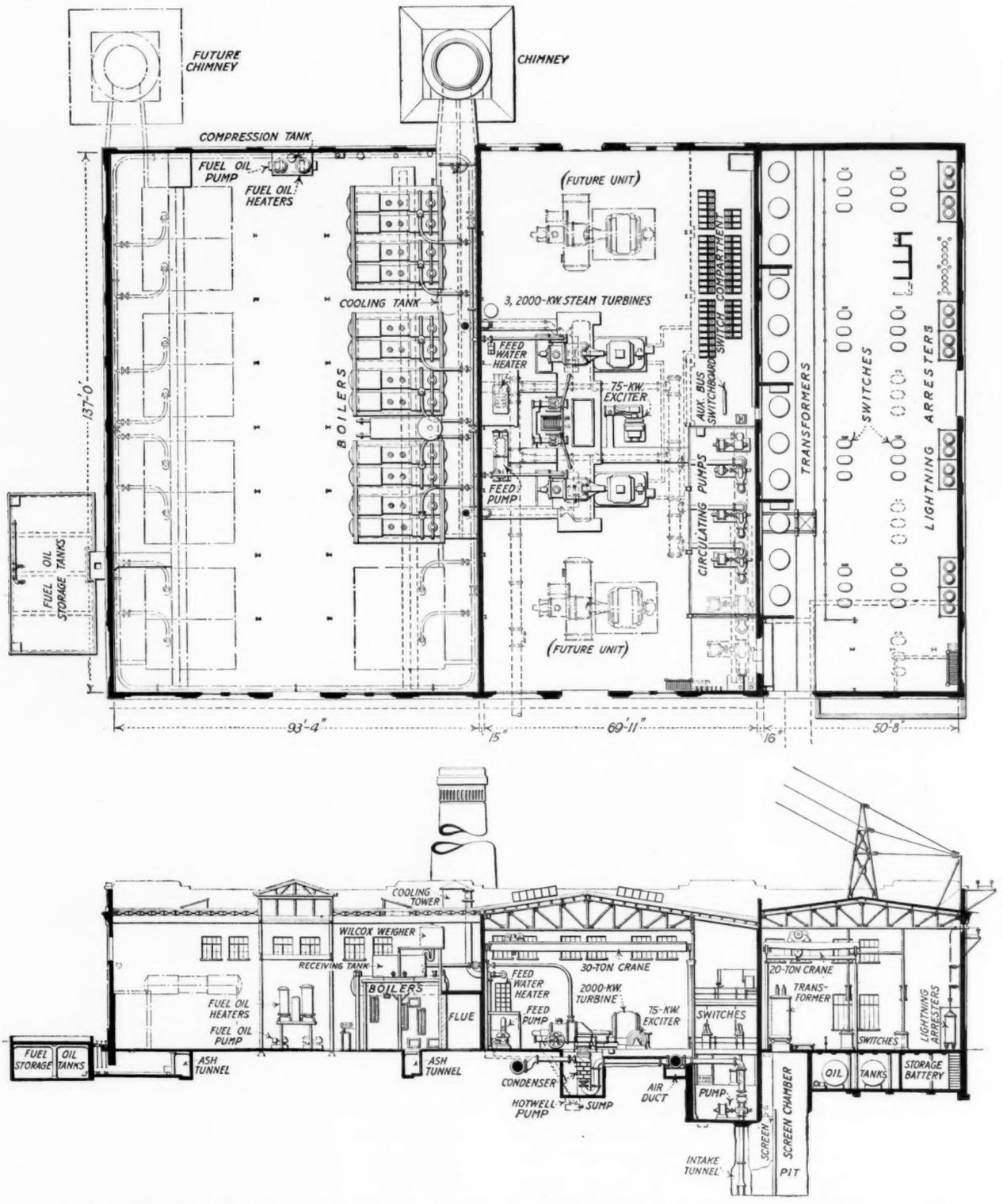


FIG. 3. PLAN AND ELEVATION OF THE PLANT, SHOWING THE ARRANGEMENT OF THE VARIOUS UNITS

steam and water drums, 46 in. diameter and 24 ft. 3 in. long. The total heating surface of each boiler is 4780 sq.ft. They are designed for a working pressure of 200 lb., and 180-lb. pressure is carried at the turbine. This installation gives a ratio of 0.717 boiler horsepower per turbine kilowatt output.

Each boiler is equipped with one superheater, designed to give from 80 to 100 deg. F. superheat at the boiler

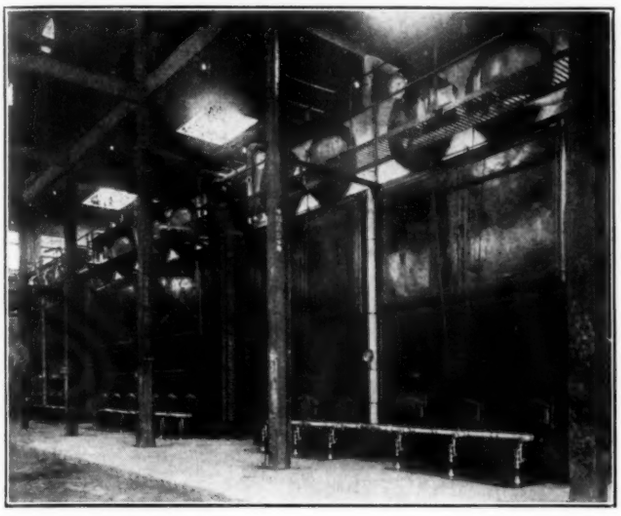

FIG. 4. BOILER ROOM OF SIX BOILERS, EACH OF 4,780 SQ.FT. OF HEATING SURFACE

nozzle when using California fuel oil. If coal is adopted as a fuel, special baffling will be necessary to prevent excessive superheat, as the same amount of surface is not necessary for coal as for oil.

Each furnace is provided with oil burners and is fired from the bridge-wall forward, but controlled at the boiler front. The distribution of flame is over a large area of boiler-heating surface, preventing localization of heat and blow-pipe action and minimizing the possibility of burning out tubes. The furnaces are arranged for the use of three burners per boiler.

The boilers are set with 8-ft. furnace heights and the ashpits have been temporarily filled in and the ash tunnels installed, so that coal stoker feed may be substituted with a minimum of expense and delay.

### Oil Storage and Combustion

The main oil-storage tanks are about 500 ft. from the plant and at an elevation, and have a capacity of 5000 bbl. each. For daily use, however, two reinforced-concrete, 600-bbl. capacity, auxiliary oil tanks were constructed below the level of the boiler-room floor. This arrangement is a protection against fire.

The combustion is automatically controlled by an automatic fuel-oil regulating system by which the oil is pumped to the burners under pressures varying from 10 to 50 lb. per sq.in., depending on the load conditions, there being a uniform pressure throughout all portions of the plant, all burners being wide open or nearly so. The amount of oil burned, with variation of load, is controlled by the pressure at the oil pumps, the intensity of the fire increasing and decreasing in all boilers simultaneously.

For atomizing purposes steam is supplied to the burners by a separate low-pressure main, the pressure in which is automatically controlled by variations of the pressure in the oil main.

The air supply for combustion is controlled by a damper controller, also automatic in its action, which increases the damper opening with an increase in oil pressure and vice versa. The movement of the controlling lever is governed by the action of the oil pressure on a diaphragm, and is opposed by the action of a spring, so that the amount of motion on the main lever is proportional to the oil pressure. The movement is multiplied through a hydraulic cylinder connected to a rockshaft running over all the boilers in one panel. Each boiler damper is connected to this shaft, and connecting levers are set at such angularity with respect to the connecting-rods operating the dampers that the proper air supply is provided over the range of load, the final adjustment being from actual trial at the plant.

Water for the plant is obtained and delivered to a 50,000-gal. tank near the plant from Durant's Lake, four miles distant and at an elevation of 500 ft.

PRINCIPAL EQUIPMENT OF THE AUXILIARY STEAM PLANT FOR VANCOUVER ISLAND

| No. | Equipment | Kind | Size | Use | Operating Conditions | Maker |
|---|---|---|---|---|---|---|
| 2 | Turbo-generators | Horizontal | 2000-kw. | Main units | 1800 r.p.m., three-phase, 60-cycle, 2300-volt, 180 lb. steam, 80-100 deg. superheat | Allis-Chalmers Co. |
| 1 | Generator | Direct-current. | 75-kw. | Exciter | 125-volt, engine driven | Canadian General Electric Co. |
| 1 | Generator | Direct-current. | 75-kw. | Exciter | 125-volt, motor driven | Canadian General Electric Co. |
| 1 | Engine | Side-crank | 110-hp. | Driving exciter | 180 lb. steam, superheated 80-100 deg. | A. L. Ide & Sons |
| 1 | Motor | Induction | 110-hp. | Driving exciter | Three-phase, 60-cycle, 2300-volt | Canadian General Electric Co. |
| 2 | Condensers | Surface | 4000 sq.ft. cooling surface | With main turbines | 28-in. vacuum | Wheeler Condenser & Eng. Co. |
| 2 | Pumps | Rotative, dry air | | With surface condensers | Steam-actuated | Wheeler Condenser & Eng. Co. |
| 2 | Pumps | Hotwell | 2½-in. | With surface condensers | Turbine-driven, 2400 r.p.m. | Wheeler Condenser & Eng. Co. |
| 2 | Turbines | Kerr | 7½-hp. | Driving hotwell pumps | 2400 r.p.m. | Kerr Turbine Co. |
| 3 | Pumps | Centrifugal | 14-in. | Circulating water | Turbine-driven | Wheeler Condenser & Eng. Co. |
| 2 | Turbines | Kerr | 50-hp. | Driving circ. pumps | 180 lb. steam | Kerr Turbine Co. |
| 1 | Motor | Induction | 50-hp. | Driving circ. pump | Three-phase, 60 cycle | Canadian Westinghouse |
| 2 | Pumps | Duplex | | Boiler feed | Steam-actuated | Warren Steam Pump Co. |
| 1 | Heater | Open | 2000-hp. | Heating boiler feed | | Harrison Safety Boiler Works |
| 6 | Boilers | Water-tube | 4780 sq.ft. heating surface | Steam generators | 200 lb. steam, oil-fuel fired | Babcock & Wilcox, Ltd. |
| 6 | Superheaters | Babcock & Wilcox | | With boilers | 80-100 deg. superheat | Babcock & Wilcox, Ltd. |
| 8 | Burners | Oil, Leahy | No. 4 | In boiler furnaces | Automatically controlled | Leahy Mfg. Co. |
| 1 | Reg. system | Moore | | Controlling fuel oil | Automatic | Chas. C. Moore & Co. |
| 1 | Chimney | Concrete | 246 ft. high, 11 ft. inside diam. | Flue gases | Natural draft | Chas. C. Moore & Co. |
| 18 | Oil furnaces | Peabody patent | | Burning oil | Three burners per boiler | Babcock & Wilcox, Ltd. |
| 4 | Transformers | | 200-hp. 1500-kw. | Stepping up from 2300 to 11,000 volts | | Canadian General Electric Co. |
| | Lightning arresters | Aluminum, electrolytic | 5000-kw. | On high-tension lines | | Canadian General Electric Co. |
| 4 | Oil switches | High-tension | 60,000-volt | Controlling high-tension lines | | Canadian General Electric Co. |
| 2 | Motor generators | 500-kw. | | | | Canadian General Electric Co. |
| 1 | Fire pump | Centrifugal | 750-gal. | For fire purposes | | Platt Iron Works. |
| 1 | Turbine | Kerr | 100-hp. | Driving fire pump | | Kerr Turbine Co. |

The turbo and motor generators are connected to the 2300-volt busbars through a flexible system of switches, so that any piece of apparatus can be isolated from the rest of the plant. These switches are controlled from a switchboard placed on a gallery in the annex of the turbine room.

In the high-tension switch room the necessary switches for controlling the following high-tension lines are provided: Two three-phase, 60,000-volt, outgoing lines to Rock Bay substation, Victoria; one three-phase, 60,000-volt, incoming line from the Jordan River plant; one three-phase, 60,000-volt outgoing line to the Tod Inlet and the Bamberton cement works. Each of these circuits is protected by aluminum-cell lightning arresters.

Necessary switches are also provided for two three-phase, 11,000-volt power feeders, and two 600-volt, direct-current interurban-railway feeders. These switches are controlled from the 16-panel slate switchboard from which the generator switches are operated. For this purpose a 60-cell, 300-amp. storage battery is used.

# Draft in Furnaces and Flues

By E. G. Bailey*

*SYNOPSIS—Another excellent article on the subject of draft. Considers chiefly why there is less draft at some point or points beyond the furnace than there is in the furnace itself.*

The subject of draft seems to be more or less confusing in connection with flues and the gas passages through boiler settings when there is considerable resistance, together with variations in direction of travel, temperature and rate of flow. It is the purpose of this article to discuss some of these points.

Draft readings used to be given in quarter-inches and sometimes as close as eighths, nearly all measurements being taken at the base of the chimney, or in the main flue beyond the boiler damper. In more recent years draft is measured to hundredths of an inch of water and readings are taken from three or more different parts of the setting. Ultimately we will be getting readings expressed in thousandths of an inch and air will be supplied for combustion as carefully as steam is supplied to an engine or turbine; that is, in proportion to the load instead of in proportion to ignorance. But draft measurements by the ordinary gage so generally used are sufficiently accurate to explain conditions that have puzzled many engineers.

In recent years I have been asked many times why it is that there is less draft (or a higher pressure) at some point beyond the furnace than there is in the firebox. The question implies that the gases flow from a lower to a higher pressure instead of vice versa.

The recently published "Bulletin No. 78" of the Engineering Experiment Station of the University of Illinois, entitled "A Study of Boiler Losses", by A. P. Kratz, also brings up this point and gives complete and convincing data in connection with a Babcock & Wilcox boiler. Figs. 1 and 16 of this bulletin are reproduced here as Fig. 1, the latter being redrawn with the drafts, or minus pressures, reading down instead of up, so as to be upon the same basis as the other curves here given. That there may be no confusion of terms, I will refer to draft pressures on a basis of their intensity in comparison with atmospheric pressure at the same level, using the plus or minus sign to designate whether above or below atmospheric pressure. That is, a draft pressure of —0.05 in. is greater than —0.12 in. The much-used expression that —0.12 in. is a greater or stronger draft than —0.05 in. is confusing and should be avoided. The action of gases is always pushing or forcing and never that of sucking or pulling. See U. S. Bureau of Mines, Bulletin 21. In commenting on the draft readings given in this bulletin, Mr. Kratz stated:

The curves in Fig. 16 (here Fig. 1) give the drafts throughout the boiler setting. The positions plotted as abscissas refer

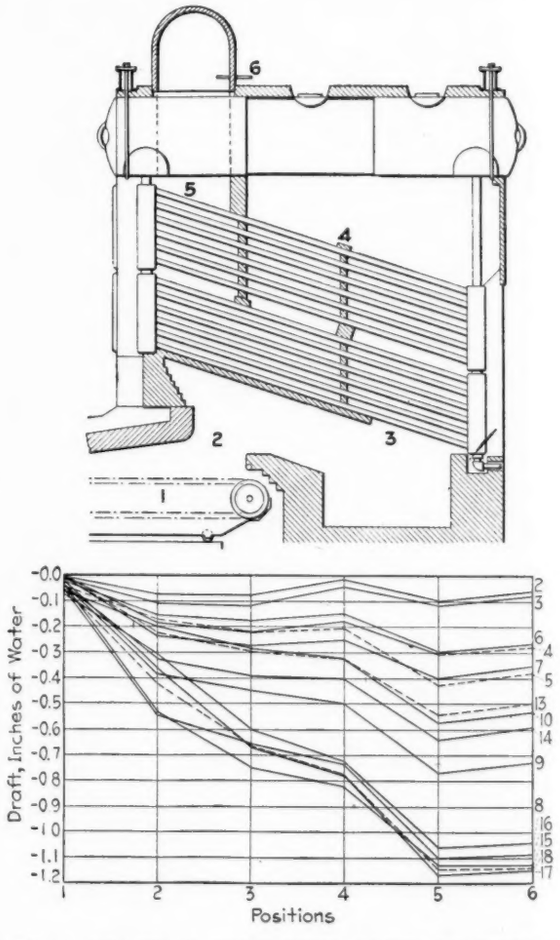


FIG. 1. DRAFT IN DIFFERENT PARTS OF BOILER

to the draft-gage positions indicated in Fig. 1. It may be noticed that there is an unexpected drop (here a rise) at positions 4 and 6. At first it was supposed that this was due to error either in the gage itself or in the position of the tube. All the gages were then calibrated and found to be well within the limits of accuracy. The positions of the tubes were also changed, and they were moved backward and forward across the channels, with the same result each time. On comparing the cross-sectional areas of the various passes

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**It was found that the area at point 4 was greater than that at point 3. Also that the wall forming part of the last pass was corbeled so that the area at point 6 was greater than that at point 5. This peculiarity in the curves, therefore, has been attributed to the dynamic effect of the flowing gases.**

If the static-draft pressure is so much affected by the change in area or temperature caused by the venturi action, as stated by Kratz, why is it that the pressure at 4 is higher than at 3 for the lower rates of gas flow, while at the higher rates of flow the reverse is true? The change in static pressure between two points, owing to the venturi action varies substantially as the square of the velocity. The pressure drop due to resistance varies in about the same way, so if this change in velocity were the principal factor, it would seem that the pressures at the different points should hold nearly the same relation to one another at all rates of flow, and the actual increase in pressure at 4 over that at 3, as measured in inches of water on the draft gage in test 15, would be nearly four times as much as in test 3.

The maximum change in static pressure can never exceed the dynamic head, such as would be measured by a Pitot tube placed in the path of the gas at the point of highest velocity. By assuming different velocities and densities of gas this head can be calculated from, $h = \frac{v^2}{2g}$. This gives $h$ in terms of the height of a column of the same gas, which should be multiplied by $\frac{12}{62.4 \times \text{cu.ft. per lb. gas}}$ to get the equivalent inches of water. Table 1 gives such values over the range of

TABLE 1. DYNAMIC, OR PITOT, HEAD IN INCHES OF WATER

| Velocity of Gas, Ft. per Sec. | Temperature of Flowing Gas, Deg. F. 500 | 1,000 | 1,500 | 2,000 | 2,500 |
|---|---|---|---|---|---|
| 5 | 0.0031 | 0.0020 | 0.0015 | 0.0012 | 0.0010 |
| 10 | 0.0124 | 0.0081 | 0.0061 | 0.0048 | 0.0040 |
| 15 | 0.0280 | 0.0182 | 0.0136 | 0.0108 | 0.0091 |
| 20 | 0.0500 | 0.0320 | 0.0240 | 0.0190 | 0.0160 |
| 25 | 0.0780 | 0.0510 | 0.0380 | 0.0300 | 0.0250 |
| 30 | 0.1120 | 0.0730 | 0.0550 | 0.0430 | 0.0360 |

temperatures and velocities common to boiler-furnace practice. From this table we see that if gas at 2,500 deg. F. was flowing at 20 ft. per sec. its total dynamic head would be only 0.016 in. water, so that if it were conducted into an infinitely large space and its velocity thereby reduced to zero, the increase in static pressure in the enlarged section could not exceed 0.016 in.; or, if the area were doubled so that the velocity was reduced to 10 ft. per sec., the final velocity head would be 0.004 in. and the theoretical increase in static pressure would be the difference between the two, or 0.012 in., which is insignificant in comparison with the so-called mysterious increases in pressure that have occurred. From test 3, Kratz data, we find that the pressure at position 4 is 0.07 in. greater than at position 3. Assume the temperature is 1,000 and 2,000 deg. F. respectively at the two places. From other data given the velocities of the gases have been found to be approximately 6.2 and 12.5 ft. per sec. respectively. So the increased static pressure due to change of both area and temperature could not have exceeded 0.007 in., or one-tenth of that which was actually measured.

By scaling Fig. 1 of Mr. Kratz's paper it is found that position 4 is about 7 or 8 ft. higher than position 3; if we assume an average gas temperature of 1,500 deg. F. in the first pass, and as the boiler-room temperature is 74 deg. F., we find the chimney action between points 3 and 4 is equivalent to 0.08 in. water. If we add to this the 0.007 in. due to decreased velocity and subtract the 0.07 in. actually measured, we have 0.017 in. left as the pressure drop due to the resistance of the first pass. It is therefore seen that the vertical distance between these two points and the chimney action due to the hot column of gas is the principal cause for the readings as given.

Mr. Hirshfeld[1] has clearly brought out this point of vertical height and chimney action by drawing a comparison between hydraulics and the static pressure at different levels. But in my opinion the essential points were somewhat confused by making the comparisons on the absolute-pressure basis. Draft readings are always made on a basis of comparing the pressure at a given point with the atmospheric pressure at the same elevation. Even a differential pressure measured between two points at different levels is on a basis of comparing each pressure with that of the atmosphere at the respective level, and is not on a basis of their absolute pressures. Draft readings on an absolute-pressure basis do not throw any more light upon the flow of the gas than do the readings as taken on the ordinary basis, and they do not even show whether or not the tendency for leakage would be into or out of the flue; so there does not appear to be any advantage in referring draft pressure back to an arbitrary level on the absolute basis. Illustration of chimney action is given in Fig. 2, which shows a chimney, or vertical flue, $A$, with five draft gages connected as shown, so as to measure the pressure in the chimney at three different levels—$C$, $D$ and $E$. Gage No. 1 is connected to $C$, and with the other end of its Ellison type of U-tube open to the atmosphere the reading obtained is obviously the difference between the chimney pressure at $C$ and the pressure of the atmosphere at the same level, or —0.20 in. In other words, the column of gas $CB$ in the chimney is lighter than the column of air $GF$ outside the chimney by the 0.20 in. water as shown by the gage reading. In a similar manner gage No. 5 shows a reading of —1.00 in., which means that the column of gas $EB$ in the chimney is lighter than the column of air $KF$ to the extent of 1.00 in. water. In other words, the chimney action between $C$ and the top of the chimney $B$ is 0.20 in. water; between $E$ and $B$ it is 1.00 in., and between $E$ and $C$, 0.80 in., or the difference between the other two differential readings. The intensity of this chimney draft depends upon the

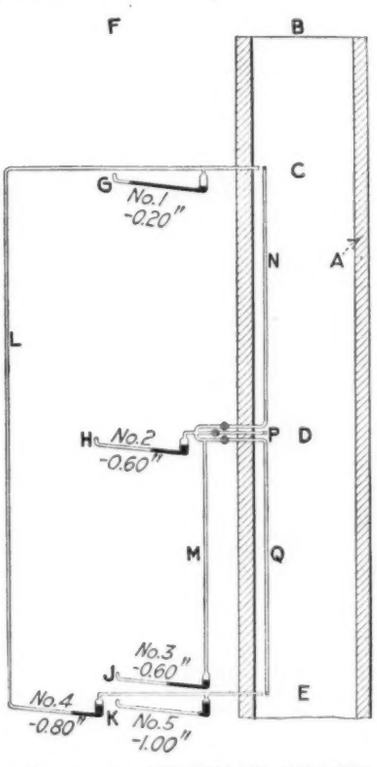



FIG. 2. DRAFT MEASUREMENTS AT VARIOUS HEIGHTS IN CHIMNEY

[1] "Power," May 18 and Aug. 10, 1915.

temperature of the gas between $C$ and $E$, the temperature of the air outside between $K$ and $G$, and the vertical distance between $C$ and $E$. The true chimney draft is based upon the assumption that the temperatures are maintained with no appreciable rate of flow or velocity in the chimney. If the temperatures and vertical height are known the chimney action can be calculated. Table 2 gives this chimney action expressed in inches of water

TABLE 2. CHIMNEY ACTION OR PRESSURE DIFFERENCE PRODUCED BY EACH FOOT OF VERTICAL HEIGHT, IN INCHES OF WATER

| Temperature in Chimney or Flue, Deg. F. | Temperature of Air Outside of Chimney, Deg. F. | | | |
|---|---|---|---|---|
| | 40 | 60 | 80 | 100 |
| 500 | 0.0073 | 0.0067 | 0.0061 | 0.0056 |
| 1000 | 0.0101 | 0.0095 | 0.0089 | 0.0084 |
| 1500 | 0.0114 | 0.0108 | 0.0102 | 0.0097 |
| 2000 | 0.0122 | 0.0116 | 0.0110 | 0.0105 |
| 2500 | 0.0127 | 0.0121 | 0.0115 | 0.0110 |

per foot of vertical height with different inside and outside temperatures.

Gages 2 and 3 will always show the same reading no matter how long the connection $M$ or the relative position, provided the temperature of the vertical connection $M$ is the same as the air between $J$ and $H$. Erroneous readings are sometimes obtained where a draft gage is located at some distance above or below the point where the tube enters the flue and the vertical connecting pipe corresponding to $M$ of Fig. 2 is close to a flue or boiler setting.

The effect produced by vertical connections within a flue is also shown in Fig. 2. The connection to No. 2 gage is divided into three branches, having a cock in each. One leads to pipe $N$ having an opening at $C$, another to pipe $P$ on a level with $D$, and the third one to pipe $Q$ with an opening on a level with $E$. If the flue is filled

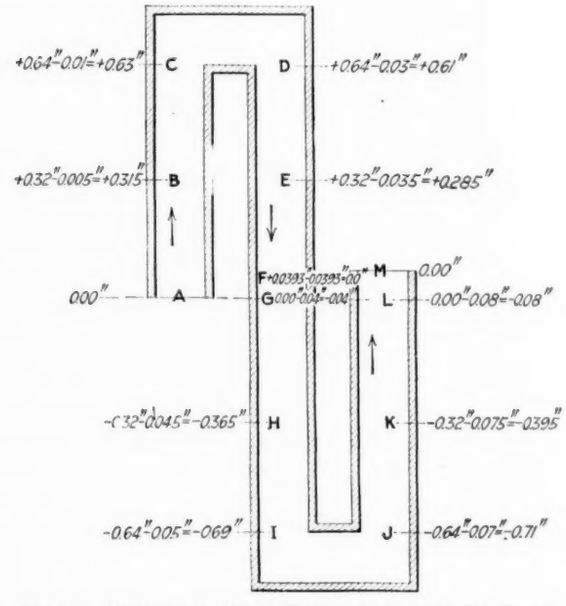



FIG. 3. SHOWING PRESSURE DROP DUE TO FLUE

with hot gases and there is no appreciable velocity, so that the pressure shown by gages 1 and 5 are —0.20 in. and —1.00 in. respectively, due to the chimney action alone, one might say at first thought that No. 2 would show —0.20, —0.60 and —1.00 in. when connected to pipes $N$, $P$ and $Q$ respectively. Upon further consideration it will be seen that it would give the same reading of —0.60 in. at each of the three points. This is because the same chimney action exists inside of $N$ and $Q$ as there is in the chimney $A$, for the pipes are within the chimney and have the same temperature as the gas. But if hot gas is flowing up through the chimney, then gage 2 will show different readings when connected to pipes $N$, $P$ and $Q$ respectively; the difference in pressure between each being the loss in pressure due to resistance to flow alone and is not affected by the chimney action between the points $C$ and $E$.

The difference between the readings of gages 1 and 5 involves both the resistance to flow and chimney action combined, and there is no way to separate the two except to calculate the chimney action from the vertical distance and temperature or density of the gas column $EC$ and the air column $KG$; but by means of gage 2 connected to points $C$ and $E$ by means of pipes $N$ and $Q$ within the chimney, the chimney action is entirely eliminated and the difference between the readings is caused by the flow of gas alone.

Fig. 3 also shows the chimney action between different levels combined with the pressure drop due to flow. Assume that a vertical flue of the shape shown is kept filled with hot air or gases at a constant temperature.

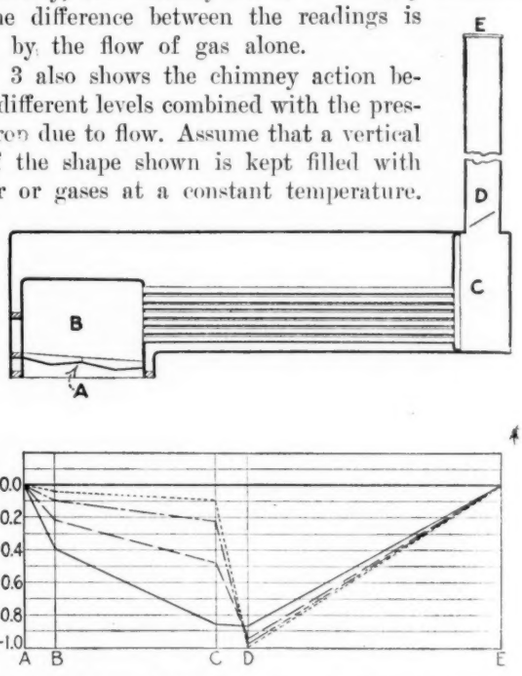



FIG. 4. DRAFT CURVES FOR LOCOMOTIVE-TYPE BOILER

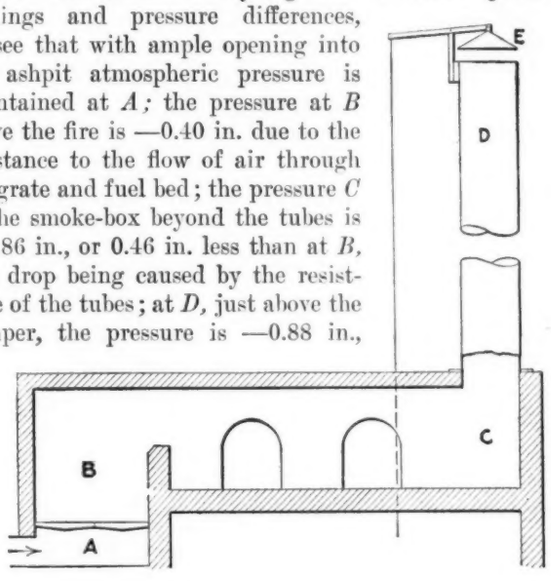
The flue may be considered to be made up of an inverted U, $AG$, and another U, $GL$, both of which have equal legs so that there would be no tendency for the hot gas to flow in either direction, but the additional length $LM$, also filled with the hot gas, acts as a chimney and causes a flow of gas through the chimney as indicated by the arrows. With a certain temperature of gases, length and area of flue, the pressures at different parts of it would be substantially as indicated, all being on the usual basis with reference to atmospheric pressure at the corresponding levels.

The draft pressures at the different points are given as composed of two parts, as +0.64 in. —0.01 = +0.63 in., the +0.64 in. being the pressure due to the chimney action produced by the column of hot gases $AC$, the —0.01 in. is the pressure loss caused by the resistance to the flow of the gas from $A$ to $C$, and the algebraic sum is the actual pressure that would be measured on a draft gage at this point as a result of both chimney action and flow. In other words, the first value at each level is the pressure due to the static head of the hot gas in the vertical flue if there were no velocity, the second value is the loss caused by friction, such as would be measured

directly if the flue were laid down horizontally and gas were flowing at the same rate, and the third value is the pressure as it would actually exist in the vertical flue as shown.

It is seen that at all points above *A* and *F* the pressure is greater than atmospheric, while it is less at all points below *F* and *M*. Gas flows upward from *A* to *C* even though the pressure is greater at *C*. The absolute pressure would be less at *C* than at *A*, but it would hold no relation to the rate of flow. On the other hand, the absolute pressure is greater at *I* than at *D* yet flow is taking place from *D* to *I*; hence we see that neither absolute pressure readings nor the ordinary comparative or differential draft readings tell very much in themselves regarding rate or even tendency to flow, because they are so greatly affected by the chimney action or static pressure due to vertical height.

Fig. 4 represents a locomotive type of stationary boiler with chimney. The full-line curve represents the highest capacity that can be gotten out of the boiler with the given chimney draft, assuming that the fuel bed is in proper condition. Analyzing the different pressure readings and pressure differences, we see that with ample opening into the ashpit atmospheric pressure is maintained at *A;* the pressure at *B* above the fire is —0.40 in. due to the resistance to the flow of air through the grate and fuel bed; the pressure *C* in the smoke-box beyond the tubes is —0.86 in., or 0.46 in. less than at *B*, this drop being caused by the resistance of the tubes; at *D*, just above the damper, the pressure is —0.88 in., or 0.02 in. lower than at *C*, the damper being wide open and offering little resistance; at the top of the chimney, position *E*, the pressure is again atmospheric. The other curves represent the draft pressures at the respective positions when there is a lower rate of flow of gases, corresponding to, say one-quarter, one-half and three-quarters of maximum capacity, the rate of flow being retarded by partly closing the damper. In this type of boiler the pressure differences are practically all due to resistance of fuel bed and flues, with practically no chimney action to complicate the problem. The pressure drop across the damper changes inversely to the damper opening, while the draft at the bottom of the chimney decreases with the increase in volume of gas passing through it, even though the temperature of the gases increased with the higher capacities.



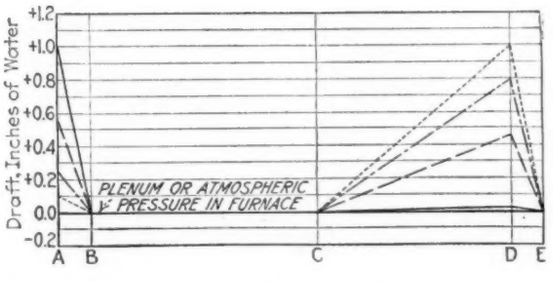
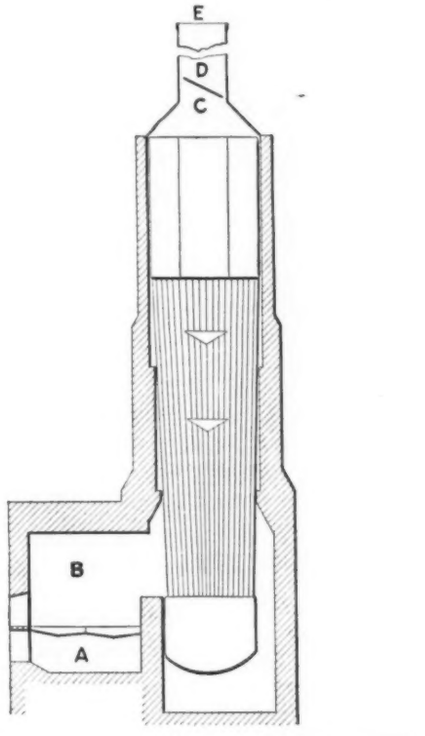




FIG. 5. DRAFT AT DIFFERENT POINTS OF PUDDLING FURNACE



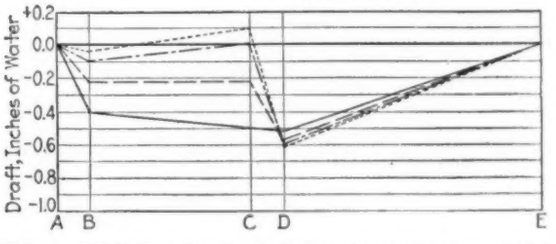



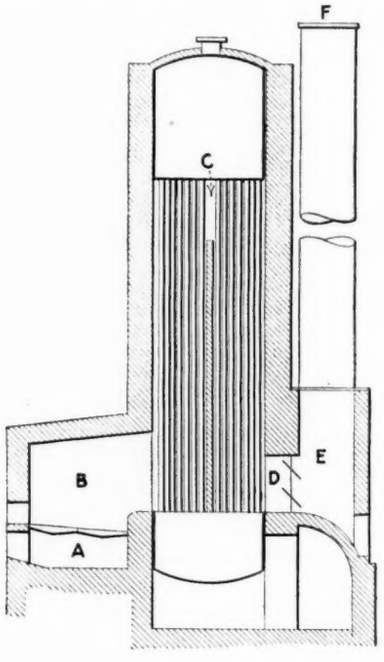

FIG. 6. DRAFT AT DIFFERENT POINTS IN CAHALL BOILER

If it is necessary to get greater capacity from this boiler than is possible with natural draft, then it will be necessary to increase the pressure at *A*, using forced draft, or decrease the pressure at *C*, using induced draft, so as to get a greater differential to increase the rate of flow through the fuel bed and flues.

Fig. 5 represents a puddling furnace and the draft pressures at different points. The air is forced through the fuel bed by a fan producing a pressure in the ashpit *A*. This pressure is increased to secure greater rates of combustion. On account of the character of the work it is necessary to maintain atmospheric pressure in the furnace, so that from *B* to *C* the pressure is zero. The chimney damper is at the top instead of the bottom of the chimney. At low rates the damper is nearly closed, yet the chimney is kept full of hot gases and atmospheric pressure maintained at the inlet, so there must be considerable positive pressure at the point *D*, just under the damper, and of course it drops to atmospheric in the free space just above the damper. At a low rate of flow the friction loss in the chimney is small, so that pressure under the damper is

practically all static due to the chimney action, but at the higher rates of flow the friction loss increases rapidly, causing a lower pressure reading at *D*, until finally the maximum capacity of the chimney is reached when the friction loss equals the static pressure due to the chimney action, and atmospheric pressure exists throughout the length of the chimney.

In the Cahall boiler, Fig. 6, the high vertical path of the gases through the boiler itself causes considerable chimney action. At one-fourth capacity there is a



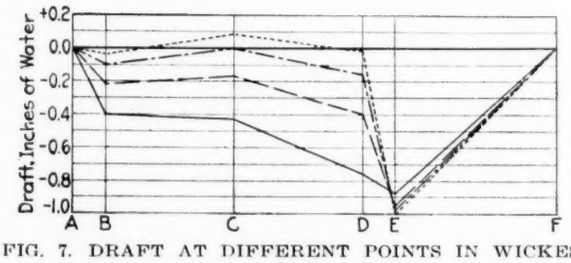




FIG. 7. DRAFT AT DIFFERENT POINTS IN WICKES BOILER

pressure at *C* of +0.10 in., and even at one-half capacity the pressure at this point is just atmospheric, although there is —0.10 in. in the firebox *B*. This means that the boiler itself would furnish chimney action enough, without any additional chimney, to operate the boiler up to this rate of output. At any lower rates of output even all of this chimney effect of the boiler is not needed, hence the positive pressure under the damper as in the case of the puddling furnace. This condition often exists, as is noted by smoke coming out through cracks in the boiler setting or flue under the damper.

At three-quarters of maximum capacity the draft at *C* is the same as at *B*, indicating that there is just enough chimney action in the gas passage of the boiler to overcome the resistance of the baffles and flues at that rate of flow, and the chimney above the boiler is really producing the draft necessary to overcome the resistance of the fuel bed. At maximum capacity the drop in pressure due to resistance of the boiler is still greater, so that the pressure at *C* is lower than at *B*.

Other vertical single-pass boilers, such as the Manning, Climax, and Porcupine, give draft conditions similar to the Cahall. The Wickes boiler, Fig. 7, gives similar draft action in the first pass, but in the second pass there is a big difference between *C* and *D* due to the negative chimney action and resistance combined. That is, the chimney action tends to produce flow in the opposite direction to the actual flow of gases. The difference in temperature also comes in here, the gases in the first pass being hotter than in the second, so that at very low rates of flow, when the resistance is small, it is possible to find a higher pressure at *D* than at *B*, even though they are both on the same level. Smoke is also frequently seen coming through cracks in the setting near the tops of the boilers when there is an appreciable draft at *B*.

It will be noted that the path of the gases through the Wickes boiler is similar to that shown in Fig. 3, also that the usual style of baffling in Babcock & Wilcox and Stirling boilers causes a similar variation in draft pressure, though to a less marked degree, owing to the lesser height and the greater resistance. This chimney action is also noted in measuring the draft at the top and bottom of a high horizontal flue, as entering or leaving an economizer.

The foregoing illustrations are sufficient to bring out the fact that the chimney action in relatively short vertical passes is sufficient to account for many of the unexpected and puzzling draft readings that have been made. Also that the effect of this chimney action is much more noticeable when the rate of flow, and therefore the pressure drop due to resistance, is low, but it exists to an even greater extent at the higher rates of flow, because of the higher temperature. It has not been more fully appreciated and understood because the majority of draft readings have been taken at the higher capacities, where the pressure drop caused by resistance predominated over that due to the chimney action.

In practically all types of boilers the up-and-down path of the gases produces so much chimney effect upon the readings at the different points that it is practically impossible to get any dependable data relative to the rate of flow of gases at different rates and baffle resistance without taking this point into consideration and allowing for it.

It is also obvious that the average fireman cannot be expected to derive much useful information from the readings of two or more draft gages connected to different parts of the boiler setting. The gages may even have a marker to show what the respective readings should be at one particular rate of output, but this has no bearing upon what they should be at some other rate of output, for, as it has been shown, the relation between them is very complicated. However, this problem, like many others, is not beyond solution, and when it is solved we will find that draft pressures will be used to good advantage as a guide in economical furnace control.

**Earliest Coal Mined in Missouri**—The occurrence of coal in Missouri appears to have been known as early as 1806, when, according to "An Account of Expeditions to the Sources of the Mississippi," by Zebulon M. Pike, it was noted on the banks of the Osage River. It is said that the early settlers opened many small mines. There is no record of the coal produced in those early days in Missouri, the first statement regarding the quantity mined in the state being contained in the report of the United States Census for 1840, which records a production in that year of 9,972 tons.

# Plan for Condensing-Water Supply for Fall River

By H. S. Knowlton

*SYNOPSIS—Four conduits in a single three-story reinforced-concrete structure to convey lake water for power, divert sewage, turn surface water into a pond for storage or into a river to waste, and convey condenser water into oil-separating and condenser basins.*

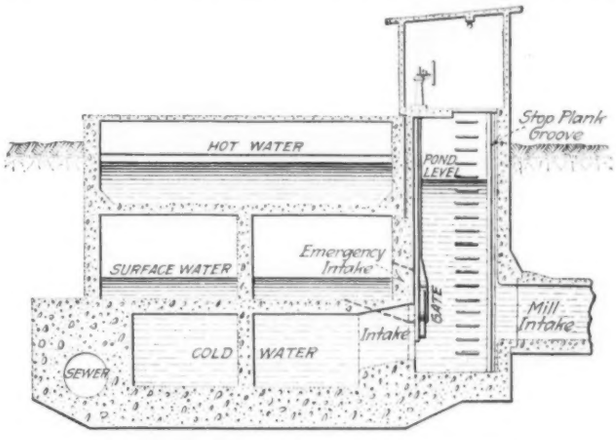
An unusual and comprehensive plan for the supply of condensing water to a large group of mills was recently presented to the Fall River (Mass.) city government by a commission created to improve the Quequechan River and conserve the waters of the North and South Watuppa Ponds. The consulting-engineering firm of Fay, Spofford & Thorndike, Boston, Mass., prepared the general scheme of development, including detailed designs bearing upon the abatement of the nuisance caused by the use of the river as a channel for sewage disposal, the investigation of the larger problems of water-supply, drainage, and the construction of proposed conduits and other structures involved in the improvement. Although the supply of condensing water to the mill plants in the river valley is but one feature of the problem, the methods proposed for its solution are of engineering interest.

At present the mills above the Watuppa Dam in the City of Fall River, largely textile establishments, when running at full capacity, develop about 55,000 hp. and consume about 90 cu.ft. of water per second, or nearly thirty million gallons per working day, principally for condensing. This amount is much greater than the normal average flow of the river and many times greater than the minimum flow during dry seasons. At flood times, when water is abundant, the mills have no difficulty in securing cool water for their condensers. With the limited flow of the stream during dry seasons, when its flats are partly exposed or are covered with a shallow flowage, it is necessary for the mills along the upper stretch of the river to use the water over and over again. Frequently the water must pass through four or five condensers in its passage from the South Watuppa Pond to the Watuppa Dam near the lower end of the stream, and under the circumstances the water frequently becomes hot and oily.

## Mills Lack Condensing Water

While the mills above the Watuppa Dam draw water from the reservoir of the flats (which are contaminated by sewage) and have an unlimited supply so long as the water can be used over and over again, those mills that are below the dam have available only such water as is at the time flowing down stream. In dry seasons, when the flow of the river is reduced to only a few million gallons a day and the water delivered at the Watuppa Dam and later discharged at tide water level has been used over and over in the mill condensers on the upper portion of the stream, the mills below suffer, not only from a scarcity of water, but from a supply that is both hot and foul.

At present the mills above the dam suffer much inconvenience during dry seasons from the high temperature of the water drawn for the mill condensers. At such seasons there is further difficulty from the lowering of the water to such an extent that only a small quantity is stored upon the overflowed flats, and this becomes heated by the action of the sun as well as by the discharges from the condensers. Temperatures of water at mill intakes in excess of 90 deg. F. are by no means uncommon; at certain mills the temperatures frequently rise above 100 deg., and it is not unusual for the river just above the dam to be at a temperature of 100 deg. or more. The water discharged from the mill condensers is at a correspondingly high temperature, frequently in excess of 130 deg., even as late as October. The loss of efficiency in condensers operated at such high temperatures is obvious. Some of the mills that take water for boiler feed from the river experience difficulties at times of low water from




CONDUIT FOR HOT AND COLD WATER

mud and other impurities that get into the boilers and pass into the engines with the steam. This applies to mills whose intakes are in shallow water. In such cases it is customary to use an extra amount of cylinder oil to afford adequate lubrication, but even then the impurities are detrimental to both boilers and engines.

Shutdowns have occurred at certain mills at different times during periods of extreme low water, owing to failure of the condensers to maintain the vacuum necessary to keep the engines running with anything like efficient operation. These shutdowns have been due either to a high temperature of the water or to its scarcity, the latter being caused either by extreme low water in the stream or by the clogging of the intakes by weeds, paper and other wastes.

In considering the water-supply to the mills, the first problem to be solved was that of providing an adequate supply of cold water in place of the limited supply of hot water now available. The only satisfactory solution of the problem was found to be that of keeping out of the river the hot water discharged from the mills, collecting it in an independent channel, clarifying and cooling it, and discharging it back into the South Watuppa Pond

for re-use in the same way. The construction of an open, walled canal, in which only the lower section can be utilized when the pond is low, was found to be needlessly expensive. An inclosed conduit, placed wholly below ground at such a level as to develop the maximum available storage of the pond and at the same time to always flow full, was found to be the most economical type of structure for supplying cold water to the mills.

The plans therefore provide for a main conduit consisting of a single structure with three separate channels superimposed upon each other, (see illustration,) to be laid along the present line of the river between the so-called Sand Bar outlet of the pond and the vicinity of the Watuppa Dam. In this conduit, which will be of reinforced concrete and practically as large in cross-section as the Cambridge, Mass., rapid-transit subway, the cold-water channel is placed at the bottom and the hot-water channel at the top of the structure, and between the two is a channel for surface water. The inlet for cold water and the outlet for hot water at the pond will be widely separated, and provision is made at the outlet of the hot-water conduit for the separation of oil and for cooling in a special basin before being discharged into the pond. Provision is also made in the design for turning the hot water into the surface-water or cold-water channels, in case of need for the prevention of interference by ice. A comprehensive system of sewers will remove present difficulties due to that source.

### Purpose of Hot- and Cold-Water Conduit

The location of the cold-water conduit underground makes it both feasible and economical to build the channel for the return of the hot water to the pond above this conduit, thereby saving the cost of foundations for the hot-water channel. The latter is to be at such an elevation that the surface of the water in it, though below the outlets of the mill condensers, will always be above the level of the pond, so that condensate may be discharged into the latter without pumping.

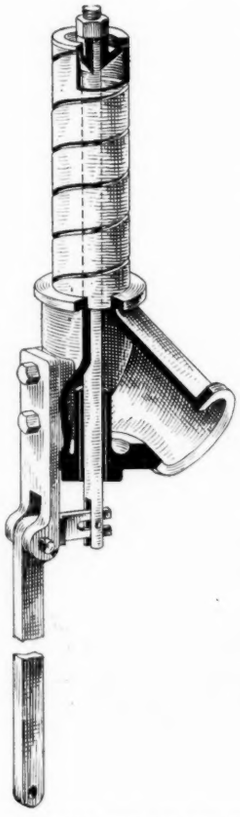
The conduit thus designed will readily supply about three times as much water to the mills above the Watuppa Dam as is used today, and this can be increased if necessary. The cold water is to be taken from the pond at some distance from the shore, at a level well below the surface and yet high enough above the bottom to avoid taking in oily water at times of storm. The clarified and cooled water from the hot-water conduit is to be discharged over a weir into the South Pond. The cold-water intake and the hot-water discharge weir are to be about 0.25 mile apart, and so located that it is believed that there will be no appreciable effect of the latter on the former. By the new plan the mills below the dam will also be supplied with adequate clean, cool water, and a uniform flow of twenty million gallons per day can be counted upon. Sixteen large mills are now situated above the dam.

In the design of the proposed work, an allowance has been made for an increase in the number of mills along the river, through reclamation of the flats. The design of the conduit assumes that ultimately the total power to be developed will be 125,000 hp. and that 225 cu.ft. per sec., or seventy-five million gallons per working day, will be required. So long as the water drawn from the conduit is returned to the pond, there is practically no limit to the amount that the mills above the dam may draw from the pond. In general, it will be necessary to provide new channels to carry the water from the present mill condensers to the hot-water conduit. These will usually consist of wooden box flumes built on the surface of the ground, which are preferred to an ultimate installation of vitrified-tile ducts, since the former will last many years and give the filling of the flats a chance to settle to a permanent level.

It is possible to return by gravity to the South Pond the water from the mill plants along the upper portion of the stream. In supplying cold water to the mills, it is proposed to utilize the present mill intakes, with such reinforced-concrete extensions as may be needed. The cold-water conduit is to be level, and the hot-water channel will fall slightly toward the pond. The cross-section of the cold-water conduit will vary from 66 to 110 sq.ft., and the hot-water conduit, whose capacity is not required to be large, will be smaller. The estimated cost of the conduit structure, with branches, is $1,655,945.

## The Thomas Spray Head

A spray head which can be adjusted for load and atmospheric conditions has lately been devised by Prof. C. C. Thomas, head of the mechanical-engineering department at Johns Hopkins University, and is being made by the C. H. Wheeler Co., of Philadelphia. The illustration shows an individual spray head, in which the construction consists of a cast-iron supporting base carrying a bronze tube wound in spiral form. This spiral tube is held between the base and a cap which fits in the top, the cap being screwed to a central bronze stem which passes down through a close-clearance bushing in the base and is operated by a bell crank having an extended arm, which gives accurate control of the position of the stem. A very small movement of the stem will vary the opening in the spiral, as it compresses or releases by the vertical travel of the cap, and this adjustment in turn controls the fineness of the film of water.



THOMAS SPRAY HEAD

In operation the water leaves the spray head in a continuous sheet in an upward direction, due to the angle of the spiral. As the film spreads it becomes thinner, owing to the increasing diameter, until the surface tension is overcome, at which point the water breaks into a uniformly fine spray. The adjustable feature provides a means of varying the thickness of the film of water and the fineness of the spray; also, the spray may be regulated to suit the load and the quantity of water at varying atmospheric conditions. This permits a relatively coarse spray during periods of high wind velocity, thus minimizing driftage. When there is little or no wind and cooling

conditions are unfavorable, by closing the spiral the spray may be made very fine, thereby greatly increasing the exposed surface of the water particles to the action of the air. This in turn creates higher evaporation and reduces the water more nearly to the theoretical temperature. The adjustable feature has another valuable function, namely, that foreign matter, such as leaves, weeds and twigs, may be readily washed out by momentarily raising the adjusting cap and releasing the tension on the spiral.

When set up in a cooling pond the adjusting arms of each spray head are connected to common levers operated from the bank, a rack adjustment being provided so that each row can be set at any desired position to suit conditions. With the ordinary nonadjustable type of spray head, on light load most of the nozzles have to be shut down and only a portion of the pond is thus utilized. By being able to utilize the whole pond area and all the spray heads at light load with the Thomas type, the cooling effect is said to be increased.

The Thomas head may be readily taken apart by the removal of the pin at the cap, the cap rod being lifted out, after which the spiral may be removed from its seat. This feature provides that all parts of the spray head may be inspected without removing it from the service pipe.

It may be added that Professor Thomas is developing this same type of spray head for a number of uses, including fire nozzles for cellar and basement fires, humidifiers, and a number of other industrial uses.

## Progress on "C., M. & St. P." Electrification

Construction work on the electrification of the western lines of the Chicago, Milwaukee & St. Paul Ry. has progressed actively since the initial work was started in September, 1914. The overhead construction, which will include 650 mi. of single track, has been completed for a distance of more than 200 mi., the 100,000-volt transmission line parallelling the track has been completed for an equal distance, and tie-in lines from the 100,000-volt system of the Montana Power Co. are ready for service. There will be fourteen substations having a total capacity

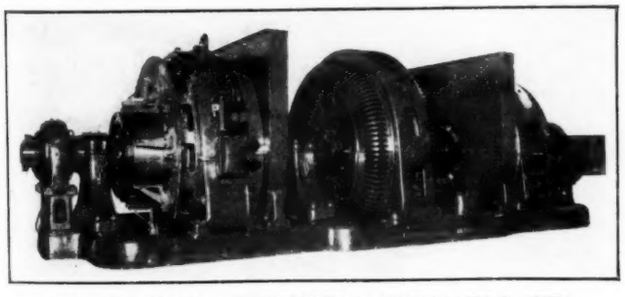


FIG. 1. ONE OF THE MOTOR-GENERATOR SETS

of about 60,000 kw. Seven have been completed, and the electrical equipment is being rapidly installed. Complete shipments of transformers, motor-generators, switchboards and other accessories have been made by the General Electric Co. for the stations first erected, and four of these are now ready for operation.

Motor-generator sets will be used instead of rotary converters, and each of these will consist of a 60-cycle, three-phase 2,300-volt synchronous motor, direct-connected to two 1,500-volt direct-current generators. The generators are connected permanently in series to supply 3,000 volts to the trolley. An exciter is mounted on each end of the set, one supplying excitation for the revolving field of the motor and the other for the fields of the direct-current machines. A special feature of the set is the longitudinal ventilation of the core and field coils, which method has effected considerable reduction in the

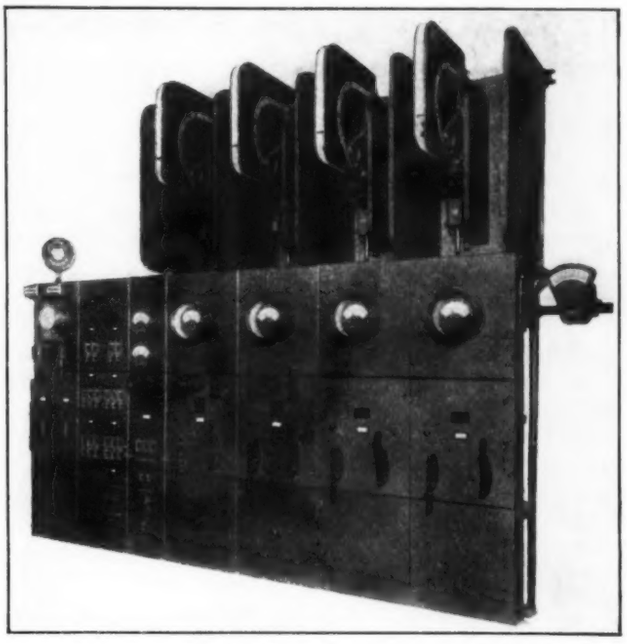


FIG. 2. DIRECT-CURRENT SWITCHBOARD

floor space required. The direct-current generators have commutating poles and compensated pole face windings to insure sparkless commutation under heavy overloads. This overload capacity is 150 per cent. for two hours and 300 per cent. of normal load for periods of five minutes.

It is interesting to note that the motor-generator sets are designed to operate inverted, in case the regenerated power of the system exceeds that required by other trains operating near-by. For this reason there is no necessity for water boxes or other energy-consuming devices, since the excess energy is transmitted to the 100,000-volt system.

The transformers are all of the three-phase core type, with a ratio of voltages of 102,000 to 2,300. For regulating purposes taps are provided for 97,200 and 94,200 volts. Taps are also brought out on the secondary windings, to give 1,150 volts, or half-voltage for starting the motor-generator sets. The transformers are oil-cooled, and the tanks are of the tubular type. An air drier and breather is attached to the tank, so that all interchange of air between the interior and the outside must take place through this channel.

In addition to the main transformer equipment, each substation will have a standard 10-kw. three-phase transformer, stepping down to 110 volts for lighting and auxiliary-power circuits. There will also be a 25-kw. single-phase transformer in each substation, stepping up to 4,400 volts, for railway signals. A portable oil-drying outfit will be used for removing moisture from transformer oil. This consists of a motor-driven pump which forces

the oil through an especially designed filter and the electric drying oven for drying the filter paper.

The main direct-current switchboard in each station is of special interest. A panel is provided for each motor-generator set and two panels for feeders, in each direction. The circuit-breakers and switches are mounted on separate panels, placed above, and a short distance back of, the main panels. A control handle for operating the breakers and switches is on the main panels and is connected to the circuit-breaker panels through insulated wooden rods. In addition to the special high-voltage direct-current panels, switchboards are also being furnished for the synchronous motors and the auxiliary circuits, of which there are many.

# Effect of Superheated Ammonia on Compressor Capacity

By H. R. Howell

*SYNOPSIS—Tells how supersaturated, saturated and superheated ammonia gas affect the capacity of the ammonia compressor.*

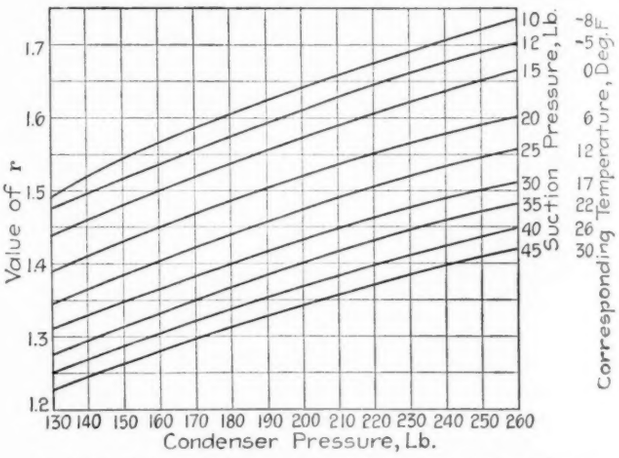
In the operation of ammonia compressors one of the most important considerations is to so operate the expansion side of the plant that the suction gas enters the compressor at, as nearly as possible, the point of saturation. The gas should not be supersaturated, otherwise the liquid entering the compressor evaporates and occupies space to the exclusion of the suction gas and thereby reduces the capacity and efficiency of the compressor.

With superheated gas returning to the compressor, a certain amount of additional refrigeration is produced, on account of the increase in the available heat per pound of ammonia represented by the product of the degrees of superheat × 0.508, the specific heat of the superheated gas. This heat is often received by the gas in passing through the suction line where passing through a non-refrigerated space, in which case no useful refrigeration results. The difference in the volume of gas at the saturation temperature for a given condition of suction and condenser pressures and that at the superheated temperature for the same pressure conditions is considerable and more than offsets the gain in refrigerating capacity due to the gas being superheated.

With compressors of the vertical single-acting type having the clearance reduced to a minimum, care is taken to so design the system that the gas is not liable to be supersaturated, as it is important that no liquid ammonia shall reach the compressors. To accomplish this in an ice plant, often the suction gas is allowed to do the work of forecooling the water for ice-making. This is, however, liable to superheat the ammonia if not given proper attention. Another way is to provide a trap through which the suction gas passes and precools the liquid ammonia on its way to the expansion coils.

## Loss Attributable to Superheating

With compressors in which the clearance is not reduced to the minimum there is much less liability of damage if liquid ammonia should enter the compressor, so it is possible to frost back heavier to insure saturated ammonia entering the compressor than with the minimum clearance type of compressor. To illustrate the loss due to superheating, assume a compressor with an effective displacement of 400 cu.ft. per min., operating at 185 lb. condenser pressure and 15.67 lb. suction pressure. The latent heat of vaporization at 15.67 lb. suction pressure is 555.5 B.t.u. The specific heat of liquid ammonia is 1.1. The temperature of the liquid ammonia at 185 lb. is 96 deg. F.; the temperature at 15.67 lb. is 0 deg. Therefore 96 less 0 equals the degrees through which the liquid must be reduced before it can be vaporized. Now 96 × 1.1 = 105.6 B.t.u. = the liquid superheat. Therefore,




CURVES TO ASSIST IN FINDING THE DISCHARGE TEMPERATURES OF AMMONIA COMPRESSORS FOR VARIOUS SUCTION AND CONDENSER PRESSURES

To determine the discharge temperature of a compressor with reference to the suction pressure, determine the value of r from the curve for the given suction and condenser pressures and use the following equation:
Discharge temperature = [(suction temperature + 460)r] — 460

555.5 — 105.6 = 450 B.t.u., the available heat per lb. of ammonia for useful work.

The tonnage of an ammonia compressor may be represented by

$$\frac{D \times A}{V \times 200}$$

Where

$D$ = Displacement of the compressor in cu.ft. per min. (allowance being made for volumetric efficiency);

$A$ = Available heat per lb. of ammonia in B.t.u.;

$V$ = Volume in cu.ft. per lb. of the ammonia suction gas;

200 = Heat equivalent of one ton of refrigeration per min.

First, take the case of saturated gas entering the compressor. We will have

$$\frac{400 \times 450}{9.028 \times 200} = 100 \text{ tons}$$

In the second case assume the same pressure conditions, but instead of saturated gas, assume that the gas enters the compressor with 20 deg. superheat. The specific heat of superheated gas being 0.508, $20 \times 0.508 = 10.16$ B.t.u., the heat of superheat. Adding this to the 450 available B.t.u. with saturated gas, we have a total of 460.16 B.t.u. per lb. of ammonia, representing the available heat with 20 deg. superheat. The volume of the superheated gas at 20 deg. and 15.67 lb. pressure = 9.58 cu.ft. (Siebel). Substituting for the tonnage,

$$\frac{400 \times 460.16}{9.58 \times 200} = 96 \textit{ tons}$$

This, it will be seen, is four tons less than obtained when the gas enters the compressor in a saturated condition. In this latter case it would be necessary to speed up the machine to obtain a greater displacement per minute, which would be necessary to take care of the greater volume of gas that must be handled because of the superheating. This of course affects the power required, resulting in a greater fuel cost in the case of a plant furnishing its own power, or greater consumption of electricity in the case of an electrically driven plant.

From the foregoing it will be seen how important it is to know the temperature of the suction gas at the compressor. Every refrigerating machine should be provided with a thermometer in the suction line close to the compressor, so that the temperature here may be ascertained at any time.

### Importance of the Discharge Temperature

The temperature of the discharge gas from the compressor is as important as the temperature of the suction gas and should be noted to understand conditions during the compression stage. The temperature at the end of compression may be found by reference to the thermodynamic equation,

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{0.23}$$

$T_2$ = Absolute temperature at the end of compression;
$T_1$ = Absolute temperature at the beginning of compression;
$P_2$ = Absolute pressure at the end of compression;
$P_1$ = Absolute pressure at the beginning of compression.

By making the proper substitutions and solving for $T_2$, we obtain the proper discharge temperature that would correspond to the given suction temperature.

To obtain the temperature at the end of compression, a thermometer should be provided close to the compressor in the discharge line.

On the accompanying chart is a series of curves representing the relation of $\left(\frac{P_2}{P_1}\right)^{0.23}$ for various suction and condenser pressures. This relation is denoted by $r$, the value of which can be readily determined from the curve for a particular set of conditions; the discharge temperature can then be found by the proper substitution in the following:

$$\textit{Discharge temperature} = [(\textit{suction temperature} + 460)r] - 460$$

In the case of 185 lb. condenser pressure and 15 lb. suction pressure, the value of $r$ from the curve is found to be 1.545. Then the discharge temperature equals $[(0 \text{ deg.} + 460) \times 1.545] - 460 = 251$ deg. If the discharge temperature is too high for a given set of conditions, it would indicate that possibly the suction valve is sticking or that the discharge valve leaks. In case the discharge temperature is too low, it would indicate that liquid ammonia is entering the compressor. For the best operating conditions freezing back to the compressor should be heavy enough so that excessive superheating will not result and so the necessity of injecting liquid ammonia into the compressor is eliminated. It is good practice to have a liquid connection to the compressor, which can be used for a short time after starting, until the frosting back reaches the compressor. By means of the expansion valve on this liquid line, the temperature of the compressor can be controlled, avoiding a large variation in temperature, which is apt to affect the compressor rod and packing.

### The Liquid-Ammonia Superheat

Another important consideration is the liquid-ammonia superheat. In case the ammonia leaves the condenser at a temperature of 95 deg. and a plant is operating at 15 lb. suction pressure, the liquid must be reduced from 95 to 0 deg. before any useful work is done. In the ordinary expansion side of a plant this cooling is done by ammonia working on itself, and the vapor thus formed passes through the full length of the expansion coils and back to the compressor without doing useful work. It therefore occupies a space in the coils to the exclusion of vapor that can do useful refrigerating work, and it also adds an amount of surplus vapor that the compressor must handle to no advantage.

The refrigeration required to cool the liquid to the back-pressure temperatures requires the evaporation of about 15 per cent. of the total liquid entering the expansion coils. Every 5 deg. that the liquid ammonia is cooled before it reaches the expansion valves results in a reduction of about 1 per cent. in the work to be done by the compressor. If it is possible to reduce the temperature of the liquid ammonia after it leaves the ammonia condenser, this should be done.

It is surprising how few plants take advantage of this gain, especially since it is such a comparatively simple matter to install a liquid cooler. In case an ample supply of cooling water is available, a cooler of either the atmospheric or double-pipe type can be used and a direct water line run to the cooler from the source of supply.

In a small plant having one or two double-pipe condensers, a good arrangement consists in having two or three additional double-pipe sections at the bottom for cooling the liquid ammonia; a branch line of the condensing water can readily be connected to these sections. Another way is by means of the suction trap mentioned, where the liquid is cooled in a spiral coil by the suction gas, or the evaporation of surplus liquid from the expansion coils which is caught by this trap.

In a plant where a cooling tower must be used or where the temperature of the water is high, a double-pipe liquid-ammonia cooler, in which the cooling is effected by the expansion of ammonia, can be used to advantage. This of course would not result in as great economy as where water cooling could be effected; however, the efficiency of the expansion coils would be increased since they would handle a greater volume of heat-absorbing vapor than if some of the ammonia was required in doing the cooling.

# Visits of Inspector Brown--IX

By J. E. Terman

*SYNOPSIS — Brown detects a boiler maker lengthening a short tube by placing a piece of hot shafting in it. The "Chief" cancels the policy on the boiler and then explains the reason why.*

"Well, Chief," said Brown after washing his hands at the bowl in the corner of the main office, "I had an illustration from a boiler maker today of how heat expands metal, when I saw a boiler maker lengthening some tubes that were too short to use in a boiler. You know the ice plant down on the river front with the three water-tube boilers? Two of the tubes were bagged in one of them, and yesterday McGinnity, the boiler maker, had the job of replacing them. The ice company telephoned in this morning that the repairs would be completed at 10:30 and wanted an inspector there to pass on them at that time. As I had a few external inspections to make in that district, Jones asked me if I would pass on the job. I reached the plant at about 10 o'clock and saw the helper run to the back end of the boiler with a piece of old 2-in. shafting about six feet long, which he stuck into one of the tubes. As the helper did not see me, I waited to watch developments. Presently, I heard the boiler maker at the front end of the boiler say, 'All right, Bill, she is through far enough now, take it out.'

### Brown Discovers How to Lengthen Tubes

"I went to the front end and asked McGinnity's man what he was doing, and he said, 'Lengthening the tubes a little.' He showed me the other tube that had been put in, but it had been expanded only in the rear header, and was just flush with the inside surface. The boiler maker said that by heating it a little, it would expand through the header the ¼ in. that we required. I could hardly believe that it was possible to expand a tube ¼ in. by placing a piece of hot shafting in it, but when Bill, the helper, did so I could see the front end of the tube push out through the header. When it came through about ¼ in., the shaft was removed and the tube rolled in place. Now, I would like to know how I can figure what the stress is on those two tubes."

"All right, Brown, I will tell you in a few minutes, after I see the manager."

The Chief went into that official's office where Brown could see him through the glass partition, talking earnestly with the manager. When the Chief returned to his office, he said: "We can proceed with our calculations now. The policy of that company has been canceled until they remove the two tubes that McGinnity put in and replace them with tubes of the proper length. You will have to go there just as soon as they get those tubes out and put wooden plugs in the tube holes in the headers and test the boiler hydrostatically, to be sure that the headers have not already been cracked. The way to treat such cases is to cancel the insurance first and make calculations afterward, for then you are sure to be safe.

"McGinnity's man is by no means the first bright boiler maker who has discovered that it is a simple thing to lengthen boiler tubes by applying a little heat. If we assume that the headers are absolutely rigid (and they are nearly so, since the ones in those boilers are made of cast iron) and assume that the adjacent tubes do not compress any, owing to the strain placed upon them, we can figure within a small error the tensile stress placed on the new tubes after they have cooled off to the same temperature as the rest of the boiler.

### Figuring the Stress on the Tubes

"To start with, the coefficient of expansion for the tube material is about 0.00000648 per deg. F.; that is, for each degree rise in temperature of the tube, its length will increase about 0.00000648 times its original length. Since the tubes in this boiler are 20 ft. long, or 240 in., each degree rise in temperature would increase their length $240 \times 0.00000648$, or 0.001555 in., and to cause them to increase ¼ in. in length, there would be required a rise in temperature of $\frac{0.25}{0.001555} = 161$ deg. F.

"This is not a very high temperature, in fact but 19 deg. have been added above the temperature of boiling water at atmospheric pressure, assuming that the boiler was at 70 deg. when they started to heat the tube.

"This temperature," said the Chief, "is based on the assumption that all of the tube length is heated to the same temperature, but the actual temperature of the portion of the tube where the hot piece of shafting was inserted was probably considerably higher than this. To find out how much stress is on those tubes when they cool off is simple, for the amount that steel will stretch within the elastic limit, under load, is a constant quantity. If we can conceive of steel being of the nature of rubber, so that a piece would stretch to twice its length without exceeding the elastic limit, in fact, behave just as the metal does when stretched a very small amount, it would require about 29,000,000 lb. per sq.in. of section to double its length, and this figure is called the modulus of elasticity of steel. Expressed in another way, we may say that a piece of 1-sq.in. section area, will stretch 0.0000000345 times its length when a load of 1 lb. is applied. This shows that the increase in length due to one degree rise in temperature is equivalent to a stretch due to a load of $\frac{0.00000648}{0.0000000345} = 188$ lb. per sq.in.

"Now, in the case of the tubes we found that the increase in temperature was 161 deg.; therefore, the corresponding stress would be, the cross-sectional area of the metal in the tube, times 161, times 188, or since those are standard-gage 4-in. tubes and the cross-sectional area of metal is 1.627 sq.in., we would have $1.627 \times 161 \times 188 = 49{,}246$ lb. This, of course, would be the maximum stress that could be obtained if all the surrounding parts were rigid, but the tubes next to those which were replaced compress some and the headers give some, so that the actual stress in the tubes may be considerably less.

"Never try to show a fellow you catch doing work of this kind that you can estimate the possible stresses in the boiler parts, but order him to cut out the tubes and replace them with some of the right length, or cancel the insurance; for this is one of the cases that you meet with in inspection work, where you want to shoot first and talk about the matter afterward."

"Well, Chief," said Brown, "I felt that there would be considerable stress on those tubes when I saw the work done, but I did not think that the matter was so serious. I can now see that if the expansion due to a rise in temperature of 1 deg. F. is equivalent to the stretch due to a 188-lb. pull, it doesn't take a very high temperature to reach the danger point, and you can depend on me, Chief, to stop the next boiler maker that I find trying such a stunt."

## "Make It Easy" Specialties

In developing its "Make It Easy" line of power-plant specialties, the Lagonda Manufacturing Co., of Springfield, Ohio, has brought out a new attachment for its grease and oil extractors (see Fig. 1). This consists of a standard to which two independent swinging arms are attached. The lower arm carries the heavy cast-iron cover to one side out of the way, and to the upper one is attached the rope hoist for lifting the linen filtering spools out of the chamber, thereby doing away with all heavy lifting in the process of cleaning. The double-seated valves shown are screwed all the way up to shut off the left-hand chamber and all the way down to shut off the other chamber, but when in the mid-position both filters are in operation. A linen winder, Fig. 2, is used to coil the filtering cloth and the woven-wire "spacer" on the spools after the accumulation of a run has been removed.

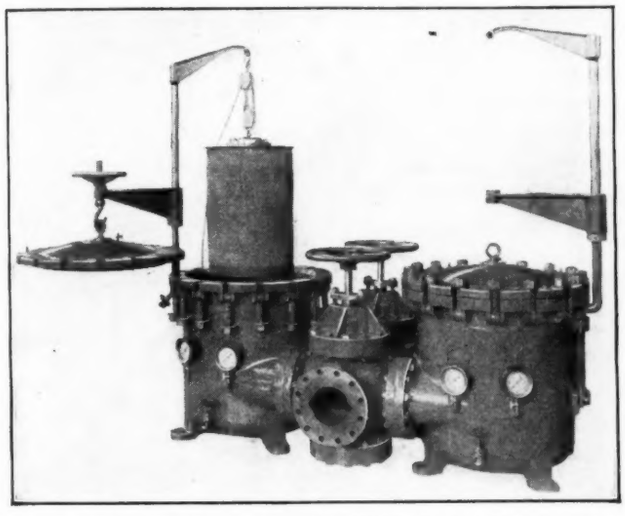


FIG. 1. LABOR-SAVING ATTACHMENT ON OIL EXTRACTOR

Figs. 3 and 4 show, respectively, the "Make It Easy" basket suction strainer in multiple and a section of one.

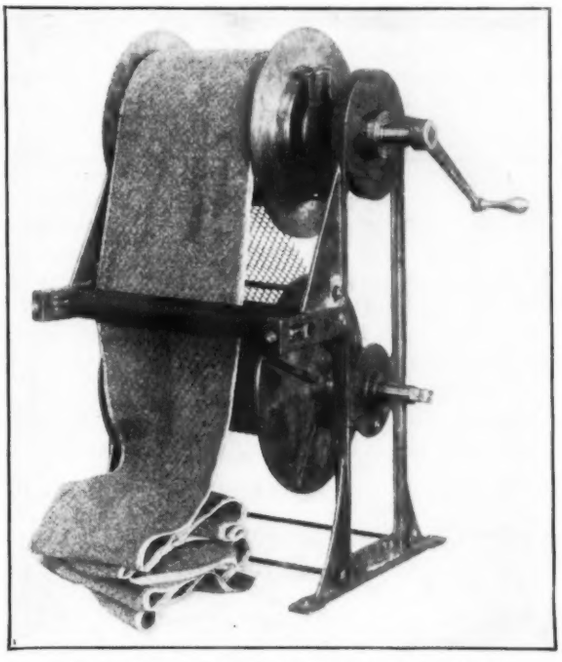


FIG. 2. WINDER FOR FILTER CLOTH

Air or other medium under pressure is admitted through the small pipe at the left extending to the bottom of the strainer chamber, and forces the strainer upward into the upper, or clean-out, chamber. The faced ring at the upper end of the strainer is at the same time forced against the finished face of the lower end of the clean-out chamber so that the flow of water is shut off. Then the hinged cover can be removed and this strainer cleaned while the others are in service.

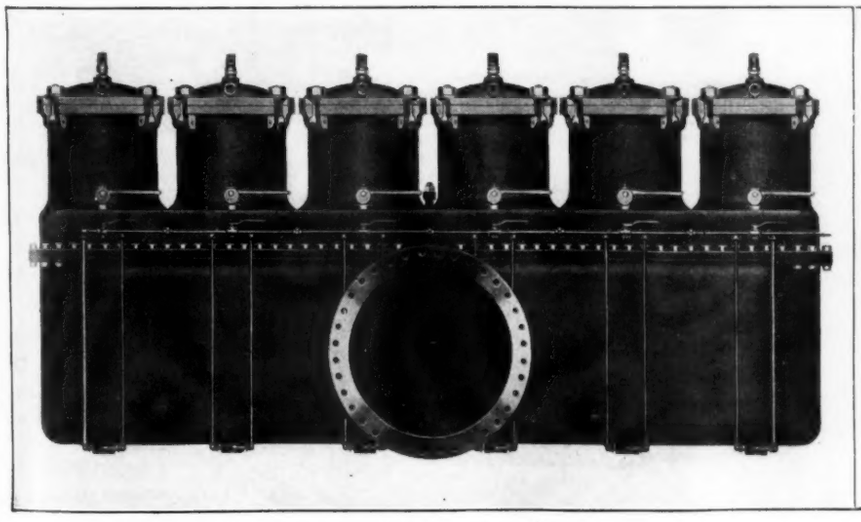


FIG. 3. BANK OF STRAINERS

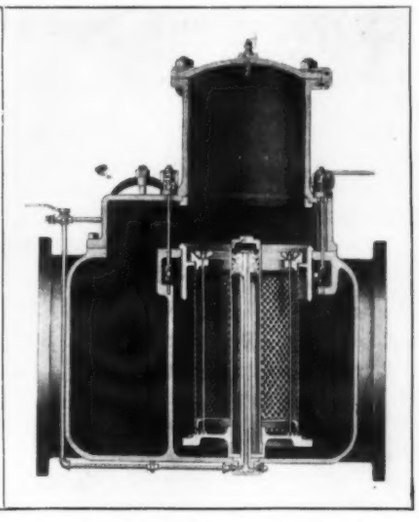


FIG. 4. A SECTIONAL VIEW

**Manufactured Ice in the United States** has an annual value of $50,000,000.

# Gas Explosions in Boilers

By Reginald Trautschold

*SYNOPSIS—Discusses the cause of gas explosions in boilers and points out how to prevent such mishaps. Pockets of carbon monoxide must be avoided and one way to do this would be to bypass a small quantity of the gas direct to the last pass to promote continuous circulation.*

From time to time a really serious gas explosion in a boiler forcibly draws attention to one of the most prevalent accidents to boilers of even the best construction and design. Each "puff," ordinarily accepted as unavoidable and usually causing little damage, is an incipient gas explosion which may result disastrously if conditions are not as they should be. Prevention of gas explosions may not be feasible, but the dangers can be minimized, and more consideration should be given to guarding against such mishaps than is customary.

### Influence of the Velocity of Gases

Unfortunately, the conditions required for an avoidance of gas explosions also tend to reduce the efficiency of steam generation, for could the circulation of the gases of combustion through the boiler setting be sufficiently rapid there would be little or no danger of a gas explosion. This would, however, lower the boiler efficiency. Heat transfer necessarily consuming time, the slower the circulation of the gases through the boiler, the greater the amount of heat transmitted to its contents, the initial temperature of the products of combustion being considered as constant. When the combustion of fuel on the grates is complete and the gases burned in the combustion chamber, the retarded circulation can safely be maintained; but when combustion is not complete and gases are driven off that still have an affinity for oxygen, any retardation to the rapid circulation becomes dangerous.

Considering only the chief component of fuel, carbon, it is first converted into carbon monoxide, which has a strong affinity for further oxygen when heated. When the fire-bed is in good operating condition and the supply of air is adequate, the carbon monoxide is converted into carbon dioxide in the combustion chamber and there is no danger of a gas explosion, no matter how slowly the gases may pass over the heating surfaces. The presence of any marked quantity of carbon monoxide in the products of combustion, from whatever cause, requires a much more rapid circulation of the gases for safety; for unless the products move comparatively rapidly, the lighter gases, which—disregarding nitrogen—are invariably the explosive ones, tend to separate from the more stable components and collect in pockets. This is the chief cause of gas explosions in boilers, and the logical way of preventing such mishaps is to make the collection of such explosive charges impossible.

Before considering ways and means of preventing the accumulation of pockets of carbon monoxide or other so-called "explosive" gases, the reason for an excess of carbon monoxide in the products of combustion, and the thermal behavior of the gases as they pass from the combustion chamber to the breeching connection should be clearly understood.

The presence of carbon monoxide is always due to incomplete combustion. It may be caused by an insufficient supply of air, so that there is not the necessary amount of oxygen present to convert all the carbon monoxide into carbon dioxide, or it may be due to an excess of air that keeps the combustion chamber temperature so low as only to maintain a state of partial combustion. That is, the first product of combustion, the carbon monoxide, may surrender its heat to a comparatively large volume of air with which it may be diffused, with the result that it is not raised to the temperature necessary for its further combination with oxygen. The first cause of excess carbon monoxide in the products of combustion, that due to insufficient air supply, is the dangerous one. The presence of too much carbon monoxide caused by excess air supply, though also to be avoided, as it seriously reduces the efficiency of the boiler, is not a dangerous condition.

### Gas Circulation and Heat Transfer

The combination of carbon with oxygen to form carbon monoxide liberates but slightly over 31 per cent. of the total heat liberated when the carbon is completely burned—that is, carbon dioxide formed—so an inadequate supply of air rapidly lowers the temperature of the combustion chamber. The volume of the products of combustion varying directly as their absolute temperature, the circulation of the gases through the boiler becomes much slower than would result only from their decreased volume due to the absence of the additional air required for completing the combustion. This, as will be seen, is the chief cause of the formation of the pockets of "explosive" gases which make gas explosions possible in boilers.

Irrespective of the constituency of the products of combustion, they commence transmitting heat to the boiler contents immediately upon passing from the combustion chamber and continue to do so throughout their passage to the stack, just as long as their temperature is above that of the boiler contents. Contrary to the usually accepted belief, this transfer of heat is nearly constant throughout the journey of the gases, slightly more heat being transmitted in the first pass, where the products of combustion are hottest, than in the last pass, where they are coldest. The rate of heat transfer varies with the difference in absolute temperature within and without the boiler, but it is the rate that varies, not the amount of heat transmitted. Transfer of heat consumes time, and this is measured by the duration of contact of a specific volume of gas with a particular section of the heating surface, which depends upon the rate of circulation of the products of combustion. The volume of the gases decreasing as they become cooler, the rate of circulation is gradually retarded so that the element of time is increased at almost the same rate at which the difference in temperature within and without the boiler decreases. This tends to a uniform transfer of heat, making nearly every square foot of heating surface of approximately equal efficiency.

The retardation in circulation of the gases depends upon the absolute temperatures, so if the gases are comparatively cool when they start on their journey through the boiler, they will be moving more slowly at the stack than if they had been at a higher temperature on leaving the combustion chamber. One advantage results from this slowing up of circulation, and that is, the gases surrender to the boiler a greater proportional amount of heat than if they traveled more rapidly and the loss in boiler efficiency is not as serious as it would be were the amount of heat delivered to the boiler proportional to the amount in the gases.

### Segregation of Components of Gas

Products of combustion containing much carbon monoxide are necessarily comparatively cool, combustion not having been complete, so they travel slowly through the boiler. The rate of circulation continues to decrease gradually as the proportion of carbon monoxide increases, until, if the process was allowed to continue, all circulation would cease. Long before all movement stops, however, the gases move sufficiently sluggishly to allow the various constituents to commence to separate, the lightest gases to rise and the heavier carbon dioxide, other products of complete combustion—soot, dust and ashes—to precipitate out of the slowly moving mass. This segregation of the various components is most marked at the breeching connection and gradually works back toward the combustion chamber as the initial temperature of the products grows less.

The "explosive" gases, being the lightest, collect in the upper passages of the boiler and form pockets of stagnant gas. Each of these pockets is a source of danger. The inert gas, nitrogen, is somewhat heavier than carbon monoxide, though considerably lighter than the products of complete combustion, and tends to collect in an enveloping blanket between the explosive and the nonexplosive gases. Complete separation of the nitrogen from the carbon monoxide would consume so much time that it is improbable whether such separation is ever completed in a boiler. The nitrogen does collect with the carbon monoxide, however, and acts as a dilutent, which is more in evidence in the lower strata of the "explosive" pockets than in the upper.

That some boilers are more likely to gas explosions than others is largely due to their construction or design. Every boiler in which the gases are forced to take a downward path in their passage from the combustion chamber to the breeching not only offers particularly convenient pockets for the collection of carbon monoxide when there is any interruption to the normal draft, but also hastens the separation of the gases of combustion by the greater loss of heat during the passage of the gases. Heated gases always tend to rise, so each time a hot gas is compelled to take a downward path there is a consumption of energy, a sacrifice of heat. This heat loss is approximately equal to that transmitted to the boiler during the unnatural passage of the gases. For instance, the temperature of the gases between the first and center steam drums of a Stirling boiler is usually about 2,000 deg. F. and at the mud drum, about 1,000 deg. F. The drop of 1,000 deg. in the temperature of the gases during their downward passage is not all taken up by the boiler. An amount represented by a drop of about 500 deg. is absorbed by the boiler, and the balance is largely expended in forcing the gases to take the unnatural path. This more rapid cooling of the products of combustion than occurs in boilers in which the path of the gases is never downward accelerates the separation of the component gases in the products of combustion.

### Cause of Slow Explosions, or Puffs

Pockets of carbon monoxide do not necessarily bring about gas explosions in boilers, even should the interrupted draft be suddenly corrected and the combustion chamber rapidly raised to its proper temperature. Both an excess of air and a supply of heat—air heated to the requisite temperature—are required before the accumulations of carbon monoxide will ignite. The removal of the cause of interrupted air supply will ordinarily also produce a rush of air through the fire bed, but frequently this air is of insufficient temperature to ignite the carbon monoxide, simply sweeping the accumulations of such "explosive" gas to the breeching, from which it may safely pass to the chimney. However, explosions do sometimes occur, ordinarily from one of two causes. The rush of excess air suddenly supplied may sweep past certain sheltered pockets of carbon monoxide which remain on the edge of the normal path until the requisite heat for ignition and the supply of air are furnished. Then the explosion takes place. Such an explosion usually consists of a gradual ignition of the carbon monoxide, and serious damage may not result.

The other common cause of gas explosions is more complicated and probably never occurs but in combination with the first. When the lack of adequate air supply which allowed the accumulation of the pockets of carbon monoxide has existed for some time, the stack draft becomes so sluggish that the contents of the chimney are practically in a state of equilibrium. With a tall stack considerable energy is required to re-start circulation, so that, though the "explosive" gases which collected in pockets might be dislodged and driven toward the stack by the inrush of air through the fire-bed or that admitted through the fire-doors, they would be driven against the inert mass of air in the stack, with the result that they might rebound toward the rapidly heating combustion chamber and encounter fresh products of combustion that would ignite the surplus "explosive" gases.

### Bypass as an Explosion Preventive

The prevention of gas explosions in all cases is the same. Make it impossible for pockets of carbon monoxide to collect within the boiler setting. That is, maintain a certain circulation of all the products of combustion as long as there is any fire on the grates. This is naturally accomplished in all boilers in which free and direct passage for the gases to the stack is provided. In boilers in which the products of combustion are forced to take devious paths and directions to reach the stack, there should invariably be provided bypasses, which would assure a certain movement toward the stack of the lighter products of combustion at all times. Carbon monoxide is lighter than air and will always escape up the stack unless confined in a pocket.

Bypassing some products of combustion directly to the stack would greatly reduce the efficiency of the average boiler and would render useless the design of many of the most efficient types. Those boilers in which the

gases are compelled to take a downward path on their way to the breeching connection offer a solution to the difficulty by the considerable loss of energy entailed in forcing the gases to take such an unnatural path. So considerable is this loss of energy that a small portion of the gases may be allowed to pass directly through the boiler and avoid the unnatural path without materially sacrificing heat on the down passages. The small quantity that it is necessary to bypass to prevent the accumulation of pockets is considerably hotter than the much larger volume of gases it encounters rising on the other side of the baffle and naturally imparts much of its heat to such gases, increasing the heat available for transmission in the succeeding pass. Just what amount of gas can thus be bypassed without sacrifice of boiler efficiency depends upon the temperature of the gases at the time they are bypassed, upon the temperature of the gases on the other side of the baffle and upon the temperature of the boiler contents; but the amount is rarely more than 5 per cent. of the total quantity of the gases and usually appreciably less.

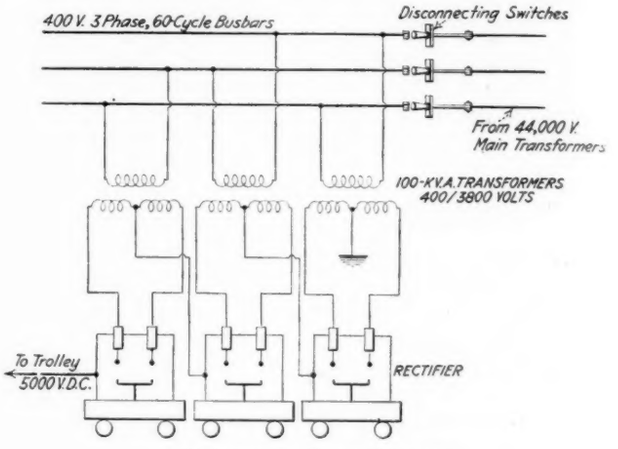
Naturally, the allowable amount of gases to bypass varies with nearly every boiler and depends upon working conditions, but can be readily calculated for any specific installation. If the small amount necessary is allowed to pass directly forward on its journey to the stack, accumulations of "explosive" gases cannot occur. A rapid circulation of the gases which otherwise might become almost stagnant is not realized, but a certain agitation that will prevent any dangerous accumulation of gases is assured as long as there is any fire on the grates which might cause them to ignite, and as long as the temperature of the products of combustion is higher than that of the outside air.

## Direct-Current 5,000-Volt Railway Operation

In the use of direct current for electric railways the trolley voltage of 600, so long considered the limit, has during the past few years increased to 1,200, then to 1,500 volts for interurban service and 2,400 volts for heavy electric traction. A further step in increasing the voltage was the electrification of the Chicago, Milwaukee & St. Paul Ry. at a trolley voltage of 3,000. Now, however, we have 5,000-volt direct current for interurban work, which has been in use since June 1 on an experimental line of the Michigan Traction Co.; this important advance having been rendered possible through the coöperation of the company's engineers with those of the Westinghouse Electric and Manufacturing Co., who worked up the details of the equipment.

Direct current at 5,000 volts is obtained from steel-tank mercury-vapor converters having their alternating-current terminals connected one set to each phase of the 400-volt three-phase 60-cycle busbars and the direct-current terminals connected in series, as shown in the diagram. This installation is the first in which mercury-vapor converters have been connected in this way to a three-phase circuit or have been used to produce so high a direct-current voltage. It is also the first case in which converters of the steel-tank type have been operated on 60 cycles.

The car equipment consists of four motors, each rated at 100 hp., 2,400 volts, connected two in series for operating on 5,000 volts. The use of such a high voltage as 2,500 at the terminals of each motor is made possible by the fact that they are of the double-armature type, in which each field frame contains two separate armatures with independent pinions meshing with a common gear




RECTIFIER CONNECTIONS

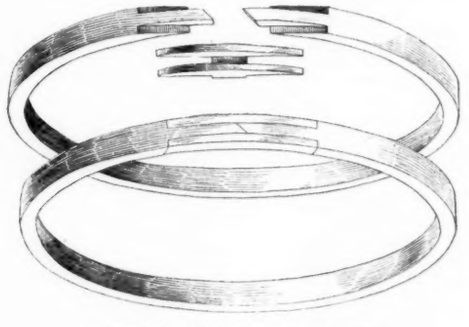
While the voltage at the terminals of the motor is 2,500, that at any commutator is limited to 1,250.

It has been found in practice that the flashing at the switches on this car, with 5,000 volts on the trolley, is notably less than when a 600-volt car is handled in the same way. This is due to the extremely small current required.

## Burd High-Compression Ring

This piston ring is designed to prevent leakage by closing the opening in the ring with a metallic guard, made and applied as shown in the illustration, and without the use of springs.

The ring ends are formed to support the guard and to retain it on the under side so as to produce a light



PISTON RING AND GUARD

contact against the cylinder wall. The rings are made of individual cast-iron rings. The skin of the casting is left on the inside as a binder to insure resiliency. The outside surface is ground under water to guard against warping during the process.

The ring is made by the Burd High Compression Ring Co., Rockford, Ill.

**When a Manufacturer Puts His Business Name** and the retail price on his merchandise, he has practically signed a contract with the public to deliver goods worth that price. His success depends upon public approval of the quality at the price.—"American Fair Trade League."

# Editorials

## Not Found Wanting in Courage

In a single issue of a London daily there appears a description of two acts requiring unusual courage that led to the presentation of medals by the King, to heroes in the engineers' crew aboard ship.

When one of the boiler tubes burst in the steamship "Vengeance," Frederick Marshall, in charge of the stokehold, with difficulty found the ladder to the upper deck, helped two men up to safety, and after two unsuccessful attempts, with a wet sponge in his mouth to reach the stop valve, put an empty sack over his head, groped along the grating and shut the main stop valve on the injured boiler. There is little doubt that if this hazardous exploit had not been carried through with such dispatch the men remaining in the stokehold would have lost their lives.

Another man to receive a medal was Stanley Robinson, second engineer of the "Oakby." When the steamer was torpedoed, she began to sink by the head and difficulty was experienced in lowering the boats, as the engines had not been stopped and were racing, owing to the propeller being out of the water. Robinson voluntarily went down into the engine room when the vessel was likely to sink at any moment and stopped the engines, thus making it possible for the boats to be lowered and get away safely.

It takes as much courage to face death in the shape of a blast of scalding steam or imprisonment in the hold of a sinking vessel as to brave the cannon's mouth, and it is pleasing to see the exhibition of such bravery recognized. It does not detract from the credit due the heroes, to suggest that, had the ships been equipped with automatic or remote control stop valves kept in working order, there would have been no call for anyone to risk his life to shut off the steam.

⁂

## Efficiency and Fraternity

An important element in any industry is efficiency. How to secure efficiency from employees is the problem, and not understanding it is wherein many fail. The foundation for it lies in coöperation between the employer and employee.

Every worthy worker is eager to do his best if his compensation is adequate, and that includes more than money. There must be the spirit of friendship, or fraternity, between man and master. The successful organizations are those that regard the men as more than machines and treat them accordingly. The average man looks upon this as appreciation of the part he is supposed to play in the attainment of profits for both parties. Making him feel that his services are an integral part of the operation and then justly compensating him solve the problem of efficiency.

Certain rules may be made for the guidance of employees, but the example set them is often more potent. One organization, and it is not alone in this respect, has placed every employee upon an equal footing. This includes the president and the officers. The humblest employee may approach the head of the plant and speak to him as man to man. The fundamental idea here is that as long as a man does his work well, he is respected and treated, not as a hireling, but as a fellow human.

A feeling of fraternity becomes apparent the moment one enters the plant. There is a spirit of friendship, a coöperation and eagerness to please seen on every face. A keen rivalry exists to outdo one another in making the work count. Thus has it been possible to attain efficiency, and without any undue effort and special slave-driving. To drive a man is to gain his contempt, and his nature will rebel at the attempt to force where kindness will accomplish more with half the energy.

With the inauguration of this policy some years ago, there was a notable change in the operation of the plant. The men took on new life, and the conduct of the employees was noticeably better. The opinions of the men on the job were asked, and the suggestions offered brought about newer ideas in operation and wonderful advances in the conduct of the entire plant. Cost cutting, labor saving, reduction in overhead, reduced friction and a better product were among the results. The men grasped the full meaning and intent of the heads of the firm, and a new life was seen in their very attitude toward one another and toward the men in charge.

To attain the ends that are worth while the confidence of the men must be gained, and money alone cannot buy the effort that is demanded of the men behind the organization, large or small, which eagerly desires greater advance. Nor can coercion or bluff accomplish anything. The right way to bring out a man's best and strongest service is through the heart.

⁂

## The Price of Accidents

Accidents, whether avoidable or unavoidable, demand and command a price far in excess of any direct monetary loss resulting from the mishaps. In the power house in particular the penalty is severe and, because the operator is an important factor, payment is exacting and a spot-cash transaction.

Power-house accidents, like any others, may be due to direct or indirect causes, but the responsibility of every employee is perforce of such high standing that the circumstances must be very extenuating to free the power force of blame. The unfortunates, if among the poorer recompensed employees, almost invariably lose their positions, but the penalty is not so easily paid. The superiors of the unlucky ones are called upon to pay their share. It may not be in immediate cash handed over to the employers or owners, but the payment is exacted from the capital of these superiors; their reputations are damaged by the loss entailed by the accident, and this reduction in their money value is equivalent to a sum whose annual interest at four or five per cent. would be sufficient to cover the monetary loss to the owners. Such fair and equitable toll cannot be avoided.

An accident that represents a direct monetary loss of only a hundred dollars must be paid for by several annual installments of the interest on a couple of thousand or more, unless the circumstances absolve the responsible ones of all blame. Rarely can the responsibility be evaded, however, so reputations usually suffer. If he who happens to be responsible for the accident is one of the low-priced men of the power house, his earning capacity, his personal capital, is not sufficient to make good the overdraft and he must pay for his carelessness, his blunder or his hard luck by the loss of his job without satisfactory recommendations to take to his next employer. The management must then engage another low-priced man to take his place, and as the newcomer's earning power in the capacity for which he is employed is not great enough to make up the delinquency charged up against his predecessor, this debit must be made up by his superiors. The toll may be apportioned among the entire power-house force, but it has to be paid.

The enforcement of the incontrovertible law requires considerable capital, and frequently the power-house owners find it necessary to charge up part or all of the just accident toll to "profit and loss," to their very decided disadvantage. In the power house, however, it is possible for the management to partly insure themselves by the wise investment of some additional capital; that is, when the resources of the plant permit such protection. This does not mean insurance against "workmen's compensation" acts, etc., for such is only protection against damage to the employees and accidents represent damage to the employers. Nor is accident insurance or insurance of equipment adequate in itself. The proper insurance is the duplication of equipment especially liable to damage through accident, so that interruptions to service may be minimized, for frequently these are more serious than the direct results of an accident.

This protection to the interests of the employers equally benefits the employees. With suitable duplication of equipment, the toll demanded of the employees by an accident is limited to little more than that covering the immediate damages caused by the accident, and even these can be greatly lessened by accident insurance carried by the owners. This protects the employees more fully than it does the owners in many instances. The owners being recompensed by the insurance company for the money loss caused by the accident, the toll imposed on the employees is that much reduced and in addition by the discount of the toll that is nearly always made by the management. If accidents are frequent, each dollar spent by the management for accident insurance benefits the employees by several dollars.

The price exacted for accidents is heavy, and though the employees must pay part of it, the greater share is paid by the employers. This division of the toll makes it imperative that all employees should fully realize their responsibilities and safeguard their employers' interest to the best of their ability. Every dollar that the employees force the employers to spend must, in part at least, be paid by them, directly or indirectly. The owners must coöperate, it is true, but if the price of accidents is fully realized by both employee and employer, much dissatisfaction is avoided and the benefits accruing to the employee are greater than those to the employer. The employees' reputations are saved, and at the same time their earning capacity is increased. This is just as true in the case of the ash handler, fireman or other low-priced employee as it is in the case of the superintendent of the power house and affects all intermediate ranks.

## The Importance of Mastering Engineering Terminology

As in many other professions, advancement in engineering in the earlier stages of one's career depends largely upon the mastery of terminology. The special applications of words and phrases that virtually constitute a technical language are so important to beginner and advanced worker alike that it is hardly possible to overemphasize the value of studying them early and late. To intelligently appreciate articles in the technical press, to read books on one's special work understandingly, to get the utmost good out of addresses and papers in engineering meetings, and finally, to converse on a basis of equality with one's fellow workers, knowledge of the language of one's profession is of great importance.

Now and then some genius, by virtue of superlative ability, succeeds without traversing the usual long and perhaps wearisome path. Such a man possibly senses almost by instinct the functions and relations of machinery, the laws and phenomena of combustion, hydraulics, steam and electricity; but most enter into these fields by the straight and narrow path of sustained effort to master successive steps slowly but surely, to perform tasks of drudgery while seeking their larger meaning, and to strive for understanding of details in the hope of fitting themselves for broader responsibilities. In all this work, especially in its preliminary stages, the habit of never letting a single word or term remain an enigma for any length of time is one of the most helpful that can be formed and continued, and a thorough mastery of the "code" of intercommunication peculiar to the profession, and indeed applying specially to different branches, is well worth striving to attain.

While the mere learning of terms will never make a successful engineer, inability to call equipment parts, processes, etc., by their accepted names, makes it difficult for most men to convince their superiors that they are capable of advancement. Terminology is thoroughly taught in any creditable engineering course, but the aspiring employee not so fortunate as to have received such special education should make it his aim, whether his work is passing coal, oiling engine-driven auxiliaries or operating an ash conveyor, to learn the names of every separate part of the equipment under his observation, so that when others discuss it in his hearing, he will add to his knowledge. Then if he is later called upon to report upon some occurrence that he has witnessed, he will be able to present his ideas acceptably, to the point and with credit to his own fitness for his work.

There is not the slightest question that the inability to use the right names in speaking of apparatus and its operation is one of the greatest obstacles to technical understanding and advancement therein.

The outcry on the part of a few of the Western states for the relinquishment by the Federal Government of all control over water powers on public lands suggests the voice of Jacob but the hand of Esau

# Correspondence

## Armature Coils Burned

Ordinarily, when a continuous-current generator carries a load under normal conditions, equal armature currents flow toward each positive brush and combine there to flow through the external circuit. This is because armature conductors under oppositely excited polepieces generate equal but oppositely directed electromotive forces. Therefore, if opposing armature sections generate opposite electromotive forces, no local circulating current will flow in the armature, even if the field be separately excited and the external circuit interrupted, thereby leaving the electromotive forces to oppose each other through the local armature circuit.

If for any reason, such as short-circuited armature coils, opposing armature sections become unequal, local alternating currents will circulate in the armature; and even if the field circuit is opened so that the only active electromotive force is that due to residual magnetism, the current flow may be abnormal because the resistances involved are small. If the machine has equalizers its efforts to equalize the armature potentials may cause sufficiently heavy currents through the equalizers to heat them and to cause the lower ends of the brushes to become red-hot.

This symptom was observed on a large 10-pole generator even when the field circuit was opened, so that all current flow was due to the electromotive force of residual magnetism. As the symptom was new, its cause was not evident. While trying to fathom the mystery, an attendant happened to hold a wrench near the head of the armature and he noticed the characteristic throb caused by an internal short-circuit. Inspection then disclosed that six adjacent armature coils were burned out. E. C. Parham.

Schenectady, N. Y.

## The Small Isolated Plant

The letter from W. G. Long, on page 384 of the Sept. 14 issue, is interesting to engineers that are familiar with small isolated plants. There is no question at all that the large power plant of 1,000 kw. or more can meet the competition of the central station, but it is seldom that the very small plant makes a showing that will equal the central-station rate, unless the exhaust steam can be used.

I recall one instance, however, where there is a very small installation that has proved decidedly more economical than the central-station rate. A single boiler and a 35-hp. single-valve steam engine supplied the necessary power, and during the winter months the exhaust steam was used for heating. The engineer was paid $2 a day and spent half his time on plant repairs. The cost of coal, which was a low-grade mixture of anthracite screenings and slack, was under $3 per day. The total operating cost, chargeable to the production of power, did not amount to over $4 per day. The manager of the plant was talked into the adoption of motor drive and central-station power. A single motor was installed, and the cost of current now averages $5.50 per day.

Of course the central-station agent has pointed out that the depreciation on the boiler isn't quite so great and that various fixed charges are not included in the cost of $4 per day. As a matter of fact, however, there is no reduction in the fixed charges, because the boiler and engine have been retained on their old foundations and it will be necessary to use the boiler in winter for heating purposes. As it will be necessary to employ a fireman and use nearly as much coal per day as formerly, the cost of heating the plant during the winter will be about the same as that previously expended for both heat and power, and in addition there will be a charge of $5.50 per day for electric current.

Needless to say, this particular manufacturer has decided to remove the motor and replace the belt on the engine. W. F. Rockwell.

Boston, Mass.

## Economizers in Modern High-Pressure Power Plants

Commenting on the letter from George C. Usher in the Oct. 12 issue, the apparent lack of confidence some engineers seem to have in cast-iron economizers for high pressures seems to have been acquired at the time when reciprocating or plunger pumps were used for boiler feeding; making possible a sudden building up of the pressure due to a quick change in speed of the pump, or due to decreasing simultaneously the quantity of water to a number of boilers. Failures of cast-iron tubes or headers have been traced directly to such sudden changes in pressure. With the high-speed centrifugal boiler-feed pumps now so generally used in large stations, sudden changes in pressure are less likely to occur.

In installations where the hot gases were from furnaces equipped with stokers that almost always smoked, the deposits of soot, with moisture present, caused rapid corrosion at any time when the temperature of the gases or air surrounding the tubes was below 212 deg. F. This corrosion naturally decreased the thickness of the metal and therefore reduced the factor of safety. With the present smokeless furnaces practically no soot is found on the economizers, the material that does come over with the hot gases being firebrick or ash particles which have a scouring action on the tube. In this case, because of the small amount of deposit on the tubes, tube scrapers are ineffective, steam blowers in some installations proving very efficient.

If high-pressure cast-iron economizers are not safe, then operation at a lower pressure could be followed. If an economizer were operated at a normal pressure of 100 lb., a temperature as high as 338 deg. for the outlet water could be reached. To secure this lower pressure in the economizer would require two boiler-feed pumps, or better,

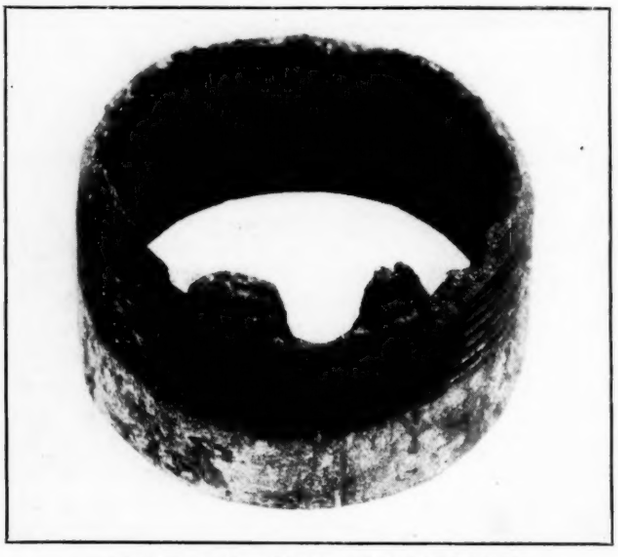
a feed pump consisting of two two-stage pumps, mounted upon the same shaft and operated by the same prime mover. Two single-stage high-speed (7,500 r.p.m.) pumps on the same shaft may also be used. Such a scheme would possibly require extra investment in pump and piping, but would be partially, if not wholly, offset by the decreased cost of the economizer for the lower pressure.

With an installation equipped for the efficient removal of deposit on the tubes and headers and proper provision made so that careful inspection can be made at any time, it appears that the economizer question settles itself into a balancing of investment and operating costs against value of gain in efficiency. NORMAN G. REINICKER.

New York City.

## Blowoff Pipe Was Defective

"Speaking of conscience," said a friend of mine, discussing the editorial, "Importance of Conscience," in *Power* of Aug. 31, "I've had an experience since I last saw you which has caused me to do considerable thinking:" showing a piece of 2-in. pipe about 16 in. long, the threaded section on one end of which, as shown



EFFECT OF LEAKAGE AND CORROSION

in the illustration, looked as though some giant-toothed animal had nibbled at it.

"One day not long ago the fireman came to me and said that he did not like to blow down No. 4 boiler because a section of the gasket was blown out of the flange joint below the blowoff valve and he was afraid of getting burned when he opened the valve. I instructed him to leave the valve shut until the next Sunday when we could put in a new gasket.

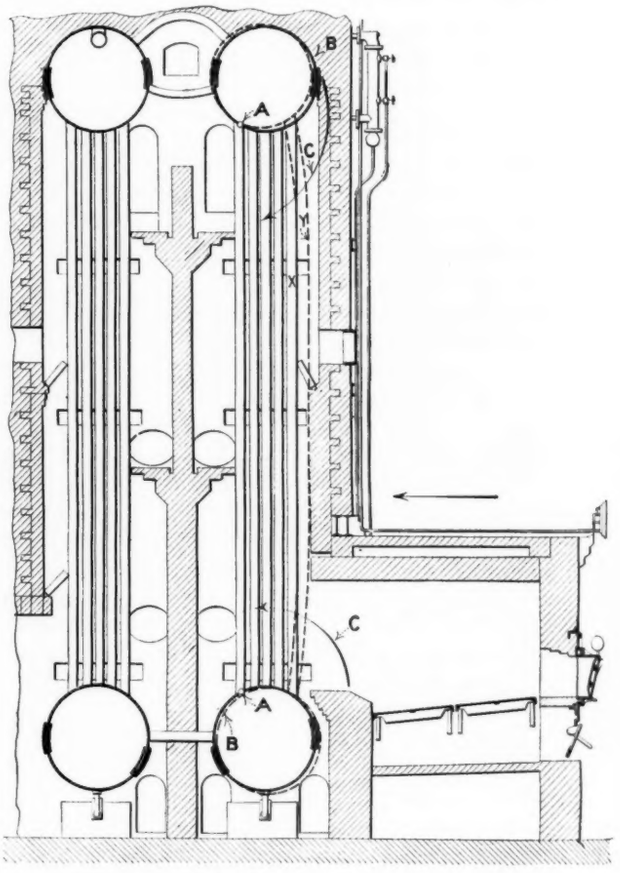
"After the bolts were all out of the flanges on each side of the valve, I lifted it off, thinking, of course, that the gaskets had let go. This was true of the flange next to the boiler, but you can imagine my surprise when I looked down and saw the pipe staring up at me with no flange on it. The flange that was on the pipe had broken off, and the gasket was holding it on the valve.

"The leak that the fireman ascribed to a blown gasket was due to the defective condition of this pipe where it entered the flange. A close examination showed that the pipe had probably only been entered a couple of threads and these had corroded off. How long it would have lasted without causing a serious accident is a question, but the man who had the job of blowing that boiler down had been in danger of serious injury, to say the least. You may rest assured that every branch blowoff pipe has been examined since this happened, and that it is going to be a regular job around here from now on, and that they will be examined too often rather than not often enough." A. T. WALKER.

Washington, D. C.

## Deformation of Boiler Tubes

Regarding the deformation of boiler tubes, as described by J. C. Hawkins, in the issue of Sept. 28, page 452, the two reasons advanced are not wholly convincing. The direction of the bend, I have found, is not always away from the fire, but in some boilers is toward the fire, and




TUBE DEFLECTION TOWARD THE FURNACE

in other types the tubes will spring both toward and away from it in the same boiler. My opinion is that it is caused by scale formation.

In the "Stirling" and "Rust" boilers the rows of tubes nearest the fire are subjected to the highest temperature, consequently are lengthened to a greater extent than the rear tubes. This tends to force apart the connecting drums, setting up a strain that causes them to revolve about a point, as at *A*, and assume the position *B*.

If these tubes contain considerable scale they may be heated to redness, structurally weakening them, and not being able to resist the strain previously set up, they are deformed by the boiler drum assuming its original position by traversing the circular paths *C*, equivalent

to a double hinged motion generated at the point *A*. These motions form two parallel forces, which have the direction indicated by the arrow over the furnace, causing the tubes to spring away from the fire, notwithstanding that by the spreading of the drums the tube *X* has had internal strains set up in it, causing it to assume, but not actually take, the form shown at *Y*. When the tube is heated to redness, these internal strains are removed as in an annealing process and the action of the drums in assuming their original position causes the tubes to receive a permanent set before they have cooled sufficiently to resist it.

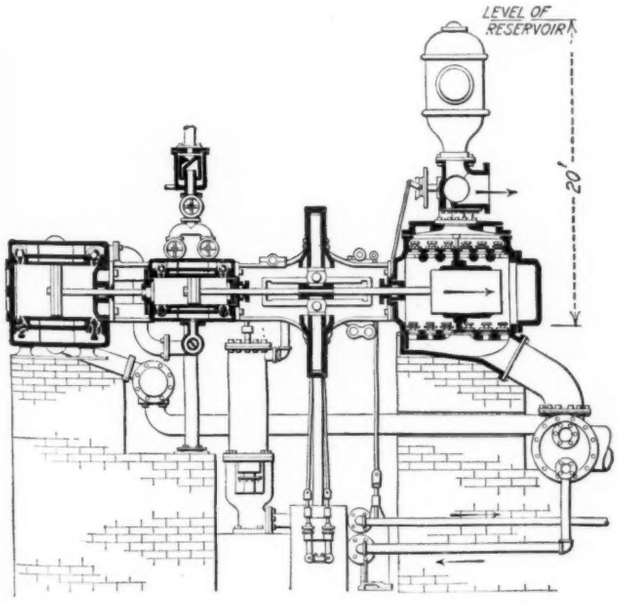
Weakening from overheating caused by the water in the tube being driven from behind loose scale is another reason why tubes spring. THOMAS R. TARN.

Pittsburgh, Penn.

## Temperature Change or Water Hammer--Which?

On taking charge of a large pumping plant I was confronted with the task of discovering the location and cause of a heavy water hammer that occurred shortly after shutting down at night. The pump is a 25&50x24x36 compound duplex high-duty Worthington, with a surface condenser on the suction line.

On examining the low-pressure cylinder I found extending 12¾ in. along the outside of the cylinder a crack which had been covered with a patch. When the pump was not running water would come out around the edges of the patch in large quantities, so I first set out to find where the water came from, then to remedy




TYPE OF PUMP, SHOWING CONNECTIONS

the trouble if possible. I removed the cylinder head and found a crack about 18 in. long on the inside of the cylinder near the head. Taking the piston out, I discovered at the other end a number of cracks varying in length from 4 to 18 in., and the ribs between the exhaust ports were cracked also. The pump could not be shut down for repairs until later in the season, on account of the urgent need for water at the time.

But I had not yet discovered what caused the cylinder to crack, although I knew it must have been water. But where did the water come from in such quantities? The throttle was found to be tight, so the only other possible place was the exhaust, which, as stated, terminated in a surface condenser. Here was found the cause of the trouble. A number of tubes leaked, and as there is a static head of over twenty feet the water naturally found its way through the leaky tubes into the exhaust and into the low-pressure cylinder. The steam pressure in the jackets was 100 lb. and the temperature somewhat over 300 deg., while the temperature of the water that entered through the exhaust was not over 50 deg. Were the cracks in the cylinder caused by this difference in temperature? It would seem that they were, because, since the old cylinder has been replaced by a new one (at a cost of about $3,000), the condenser repaired and a bleeder tapped into the lowest point, the pump has been running for five years and is in as good condition as when first put in. There is no water hammer, and the vacuum gage shows 28 in., which is a big improvement over the 21 in. before making the repairs. WILLIAM ROBERTS.

Yonkers, N. Y.

## Emery Ruins the Cylinders of a Compressor

An engineer was hired to operate this plant after it was put in service, and to familiarize himself with the equipment and keep an eye on the construction work he was put to work while the plant was under erection.

Part of the equipment was a small ice machine. While the erecting engineer was installing it, the engineer inspected the cylinders, which of course were not as smooth as they would be in a machine that had been run for a while, and he told the erecting engineer that he thought they were altogether too rough. The latter explained that they would wear down as smooth as glass in a couple of weeks or a month at the most and that all new machines were that way.

After the erecting man had left, he decided he would hurry the smoothing operation. There was a bag of fine emery left, which some of the erectors had used for grinding-in valves, and the engineer mixed this with oil and pumped a liberal dose into the steam and ammonia cylinders. After a couple of days he gave them another dose and still another at the end of the week, telling the oiler he was going to have a polish like looking-glass in a little while.

About a month later, answering a hurry-up call, the erecting man found that the head pressure was low and the back pressure high, indicating that the machine was too small for the system, which he knew was not the case. He placed the wristplate on the central position, opened the indicator connections and turned the steam on. To his surprise steam at apparently full pressure blew out of each end of the cylinder. He removed the valve bonnets and examined the valve setting, which was the same as he had left it. Then he pulled out one of the valves. This bore a sorry resemblance to the one he had put in there a month before.

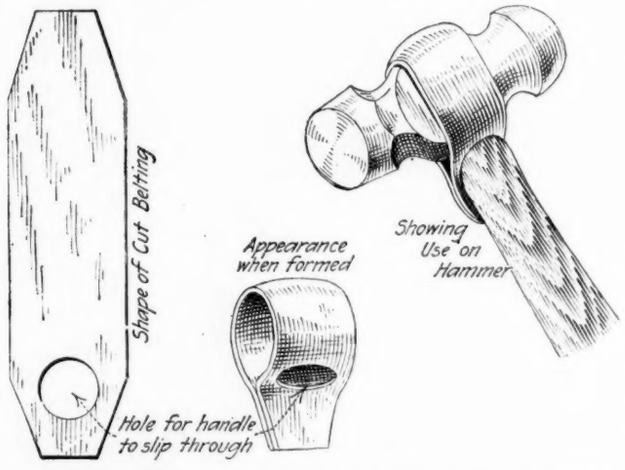
While the oiler and he were working, the former casually remarked that "Ben's emery and oil wouldn't put much polish on cylinders in such a condition." The erecting engineer nearly dropped his wrench, but managed to appear unconcerned. In a matter-of-fact way

he answered that he did not think it would, and inquired how they had used it and how much. The next day two men with a boring bar were busy on the machine and one engineer was out "scouting" for another job.

Chicago, Ill. THOS. G. THURSTON.

## A Handy Soft Hammer

A way in which to make an ordinary engineer's hammer serve in place of a mallet or wooden hammer for use on wood or other soft materials consists in using a piece of



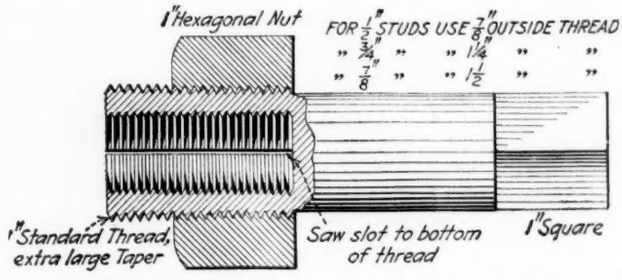

ENGINEER'S HAMMER WITH LEATHER CUSHIONING

leather or belting in the manner shown in the drawing. A hole is cut in the leather large enough to be slipped over the handle of the hammer and then brought to the head of the hammer. The flap is then brought over the head of the hammer and nailed on to the handle, or the two ends are wrapped to the handle with several turns of fine wire. The hammer is used sidewise on wood, which brings the leather belting into play, and softens the blow. In this way the user has a hammer ready for various uses in a very compact and convenient form. The leather will wear for a remarkably long time.

Washington, D. C. A. P. CONNOR.

## To Set or Withdraw Stud-Bolts

Studs may often be screwed in or taken out by means of two nuts locked together on the threads, but where this is not possible a tool made as shown in the illustration can be used to good advantage. It is made of tool


1"Hexagonal Nut
FOR 1/2" STUDS USE 7/8" OUTSIDE THREAD
" 3/4" " " 1 1/4" " "
" 7/8" " " 1 1/2" " "
1"Standard Thread, extra large Taper
Saw slot to bottom of thread
1"Square

CONVENIENT CLAMP FOR TURNING STUDS

steel large enough to be drilled and tapped to screw on the stud to be acted on. The outside is threaded to receive a large nut, and the threaded part is slotted with a hacksaw, as shown. The outside thread and that in the nut are given an extra large taper so that the nut can close the slot and cause the inner thread to clamp the stud.

To use, the nut is backed off until the inner thread goes over the stud easily, then tightened. This closes the slots and clamps the stud firmly, and with a suitable square or hexagonal head on the opposite end an ordinary wrench may be used. By the use of this tool the stud is not injured, as it is if a pipe wrench is used.

Knoxville, Tenn. F. W. FISCHER.

## Porous, Cast, Blind Flanges

An 8-in. valve on the high-pressure (750-lb.) hydraulic-elevator system of a group of office buildings was found to be leaking from a crack 6 in. long in the body. To remove the valve it would be necessary to shut down the entire plant, so the work was started on Saturday night, when the plant could be run on the auxiliary header. Two cast-steel flanges to blank off the pipe ends where the valve came out were faced off on one side and drilled for twelve 1¼-in. bolts and placed in position, but when the low pressure (80 lb.) was put on, water squirted through them in a dozen places—the castings were porous.

They were removed and taken to the shop, and a dozen steel taper pins were driven into the largest of the holes and a liberal coating of Smooth-On applied. Fiber gaskets $\frac{3}{16}$ in. thick were placed over the face of the flanges, and they were once more bolted in position. This time, when the high pressure was turned on, they held perfectly. As expected, the cement and fiber worked into the holes under the 750-lb. pressure and did the business.

Newark, N. J. W. T. OSBORN.

## The Engineer's Employer

I wish to express my appreciation of your editorial in the issue of October 15 entitled "The Engineer's Employer." Without appearing to boast, may I say that we are trying to look after the interest of our employees, not only as to their personal welfare, but also in the way of educating them to a better knowledge of our business.

To begin with, we are trying as far as possible to place all our plants on the eight-hour basis or, if that is not possible, to give every man one day's rest in seven. It is true that this is required by the New York State law, but we try to go a little farther than the law's requirements. Every man that has been with us for a year receives a week's vacation in summer, with full pay. At the end of the year every man that has been with us for the year receives as a bonus a certain percentage of his wages.

Another plan that we have adopted was suggested by the fact that several of our employees have lost babies through improper medical attention. We are therefore arranging to retain the services of a physician, experienced in maternity cases, for whose services the employees will be required to pay only a nominal fee.

We are also at work on a plan for a school for firemen and engineers, and we expect great things from this.

May I say, in conclusion, that I heartily concur with the very obvious endeavor of the editor of *Power* to better the condition of the operating man.

GEORGE W. MARTIN, Vice-President,

New York City. New York Service Company.

# Inquiries of General Interest

**Speed Required to Develop Stated Power**—A 12x18-in. engine running at 92 r.p.m. develops 42 i.hp. At what speed will the engine develop 52.51 i.hp.? L. D. T.

To develop 52.51 i.hp. with the same mean effective pressure would require a speed of

$$\frac{52.51 \times 92}{42} = 115 \text{ r.p.m.}$$

**Mechanical Efficiency of Engine**—The mean effective pressure of a 10x15 engine running 400 r.p.m. is 43 lb. per sq.in. when developing 94.15 brake horsepower. What is the mechanical efficiency? J. C. S.

The indicated horsepower would be

$$\frac{43 \times \frac{15}{12} \times (10 \times 10 \times 0.7854)\ 400 \times 2}{33{,}000} = 102.34 \text{ i.hp.}$$

and as the mechanical efficiency is the ratio of brake to indicated horsepower the mechanical efficiency would be

$$94.15 \times 100 \div 102.34 = 92 \text{ per cent.}$$

**Freezing Point of Water at Different Pressures**—At what temperature will water freeze when under 25 in. vacuum? G. B.

It has been estimated thermodynamically and verified by experiment that for every additional atmosphere of pressure the freezing point of water is lowered 0.0075 deg. C., or 0.0135 deg. F. As the freezing point of water at atmospheric pressure is 32 deg. F., then under a vacuum of 25 in., or about $\frac{25}{30} = \frac{5}{6}$ of an atmosphere, the freezing point would be 32 + ($\frac{5}{6}$ of 0.0135) = 32.01125 deg. F.

**Fire Cracks at Girth Seams of Boilers**—What are the principal causes for fire cracks at the girth seams of return-tubular boilers? J. W. D.

The principal cause for fire cracks at the girth seams is the presence of dirt on the inside of the boiler. This dirt, acting as a nonconductor of heat, prevents transfer of heat to the water and results in overheating or burning the plate, and the cracks ensue from sudden cooling of the plate, as by admission of cold air through the fire-door. Fire cracks may also be caused by sudden cooling after the edge of a plate next to the fire has become overheated as a result of too much lap of the joint.

**To Magnetize Magneto Magnets**—How can magneto magnets and other small pieces of steel be magnetized, by employing a dry battery or storage battery? T. W. M.

The simplest method is to employ an electromagnet constructed according to the materials available. Taking a bar of soft iron about 4x4x12 in., wind around it about 40 ft. of No. 10 weatherproof wire in the form of a coil. This would allow a current of about 50 amperes to pass from a 2-volt cell, and at the same time the magnetization produced would be well within the saturation limit of the iron. With such an electromagnet the magneto magnet or other piece of steel can be magnetized by placing it in contact with the iron core of the electromagnet.

**Rating of Closed Feed-Water Heaters**—What is the usual basis for rating the size or capacity of brass-pipe feed-water heaters? W. J. G.

The usual commercial rating of feed-water heaters is based on an allowance of one third of a square foot of heating surface per horsepower. According to tests, if heaters are provided with smooth clean brass tubes when supplied with abundant steam at 212 deg. F., then $\frac{1}{3}$ sq.ft. of heating surface should be sufficient for heating 30 lb. of water per hour from 60 deg. F. to 194 deg. F.; and, in view of the consumption of less than 30 lb. of water per horsepower per hour by the more economical types of engines, a commercial rating of $\frac{1}{3}$ sq.ft. of heater surface per horsepower is a rational allowance.

**Heating a Liquid with Superheated Steam**—A boiler equipped with a superheater operates at 150 hp. gage pressure and 150 deg. superheat. If the steam is piped to a closed vessel, similar to a digester, can the liquid contents of the vessel be raised and held to the temperature corresponding to the initial pressure and superheat of the steam, or will the temperature be that of saturated steam at 150 lb.? R. J. H.

The temperature of a liquid whose boiling point is the same as, or less than, that of water could not be raised to a temperature higher than that of its boiling point for 150 lb. pressure. If the boiling point of the liquid for 150 lb. pressure is higher than that of water, then the temperature could be raised to that boiling point, provided it is below the temperature of the superheated steam which is supplied.

**Jumping and Cushioning of Pump**—What would cause one side of a duplex pump to jump at the beginning of the stroke and move much too slow at the end of the stroke? M. R. B.

Jumping may be due to a throttled suction, and slowing down toward the end of the stroke may be due to a throttled or obstructed exhaust pipe. If the trouble is in the pump, it may be that the steam valve does not travel centrally, causing back-pressure on the exhaust side of the steam piston. Leaky steam piston rings also would cause the piston to be cushioned. To test whether the piston rings are steam-tight, throttle down the discharge to reduce the speed of the pump and then open the cylinder drain cocks, one at a time, and observe whether there is indication of a clean cutoff of steam. If not, steam leakage is taking place, either by the steam piston rings or else the slide valve.

**Loss from 5 Per Cent. Moisture in Steam**—When steam at 125 lb. gage pressure is generated from feed water at 150 deg. F., and contains 5 per cent. of moisture that is removed by a separator and discharged as waste, what is the percentage of waste in coal? F. W. S.

As shown by the steam tables, when steam is generated at 125 lb. gage, or 140 lb. per sq.in. absolute, each pound of the liquid present contains 324.6 B.t.u. above the heat contained at 32 deg. F., and when converted into dry saturated steam, each pound contains 1,192.2 B.t.u. above 32 deg. F. With the temperature of the feed water at 150 deg. F. (or 150 — 32 = 118 deg. F. above 32 deg. F.) each pound of the liquid would receive 324.6 — 118 = 206.6 B.t.u. and each pound of dry saturated steam would receive 1,192.2 — 118 = 1,074.2 B.t.u. But with 5 per cent. of moisture in the steam, from each pound of the feed water only 95 per cent. of 1,074.2, or 1,020.49 B.t.u., would be realized, and as the loss per pound of feed water would be 5 per cent. of 206.6 = 10.33 B.t.u., the waste of fuel would be

$$\frac{10.33 \times 100}{1{,}020.49 + 10.33} = 1 \text{ per cent.}$$

**New York's New Electrical Code**—Under the new "Electrical Code" that recently went into effect in New York, does an operating engineer have to take out a license for overhauling and repairing electrical machinery? G. G.

Sec. 6, Art. 1, of the new code states that no person shall install, alter or repair electric wiring or appliances for light, heat or power in any building unless he holds a license or special permit, or unless he be employed by or is working under the supervision of the holder of such a license or permit; and then only after an application for a certificate of inspection of such installation, alteration or repair. The term "appliances" is defined as all electrical apparatus or fittings, except fuse renewals, incandescent-lamp renewals and portable devices which, together with their cables and attachments, have been approved for connection to appropriate parts of the permanent electrical equipment. This provision does not apply to generating stations, substations or service switches of public-service corporations, or to electrical equipment used in connection with railroads.

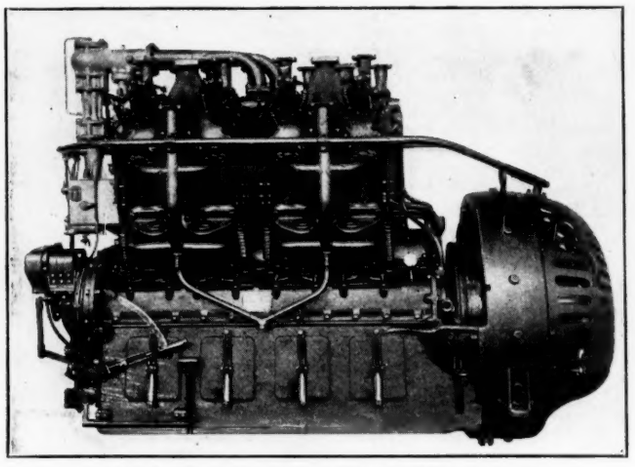
From the foregoing it will be seen that such work must be performed by the electrician, and if none be employed the engineer must take out a license or permit. A license fee of $10 is charged, with an annual fee of $5 for renewals. A special license, or permit, costs $1. Application for a license or permit must be made to the "License Board," Department of Water-Supply, Gas and Electricity, Municipal Building.

[Correspondents sending us inquiries should sign their communications with full names and post office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]

## Gasoline-Electric Locomotives

Three 60-ton gasoline-electric locomotives for freight and passenger service have recently been placed in commission by the Minneapolis, St. Paul, Rochester & Dubuque Electric Traction Co. The motive power is supplied by two gasoline-electric generating sets, each consisting of a 175-hp. 550-r.p.m. 8-cylinder four-stroke-cycle gasoline engine of the "V" type directed-connected to a 600-volt commutating-pole compound-wound generator, with an outboard bearing supported by brackets bolted to the magnet frame. The engine cylinders are 8 in. in diameter by 10 in. stroke. Ignition is furnished by low-tension magnetos, and the sets are started by compressed air. In this connection it is necessary only to start one set, and afterward the second may be started from the first electrically. Starting air is taken from the air-brake system.

Greater flexibility of control and economy of operation are said to result from the electrical transmission rather than having the engines drive the locomotives direct. Moreover, irrespective of the speed of the locomotive, the engines can rotate at normal speed and deliver their



GASOLINE-ELECTRIC GENERATING SET

maximum power—a feature of great advantage on grades.

The gasoline pumps are of the plunger type, the main pump being driven directly from the engine; the auxiliary pump is hand-operated for filling the carburetors when starting. Positive lubrication is provided under pressure.

The electricity generated is transmitted to four 600-volt series commutating-pole motors of 100 hp. each. Two motors are connected permanently in parallel, and the two pairs, operated like single motors, are placed progressively in series and in parallel. The controller provides seven running steps in series and six in parallel, without rheostats in the main circuit. There are also two additional points for shunting the series field, making a total of 15 efficient running points. To produce smooth and rapid acceleration the speed changes of the motors are effected by governing the voltage through varying the strength of the generator field. This is accomplished by movement of the controller handle. A separate handle is provided for reversing through change in the motor connections in the usual manner without stopping the engine, which allows it to rotate in the same direction. This enables a train to be brought to a halt quickly, independent of the brake in an emergency.

The outfit was furnished by the General Electric Co.

## Broken Crankshaft Wrecks Compound Engine

As a result of the breaking of the crankshaft of a 400-hp. Westinghouse vertical steam engine, running at 240 r.p.m. and directly connected to a 250-kw. 650-volt railroad generator, the engine was badly wrecked (Fig. 1).

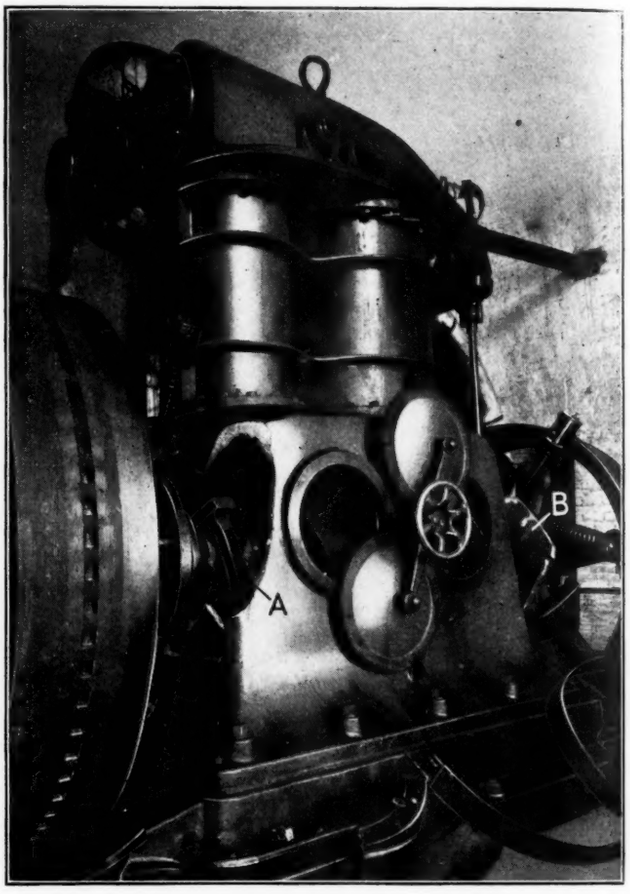



FIG. 1. BEARINGS BROKEN FROM ENGINE BASE

The break in the crankshaft (Fig. 2) started at the inside edge of the crankpin on the side next to the center bearing and extended straight across the metal. The outside edge of the crack showed by its discoloration that the beginning of the crack was old. The crank-rod was broken and both outside bearings were smashed off, carrying with them a portion of the crank-case casting.

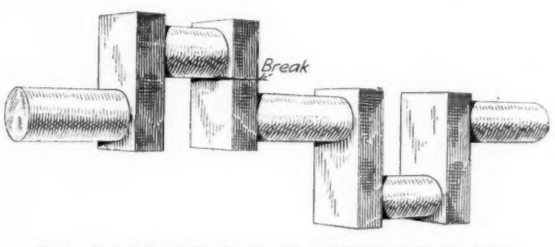



FIG. 2. WHERE THE CRANKSHAFT BROKE

as shown at *A* and *B*. The center bearing was also wrenched from its bed. The end of the shaft supporting the generator was bent, and the brush holders were thrown out of place, slightly damaging the armature. After the first crash the engine made a few revolutions and then stopped. Fortunately no one was injured.

# The Steam Boiler of 1915*

By Arthur D. Pratt†

*SYNOPSIS—Unit capacities have increased in a decade from 500 or 600 to over 2,000 rated hp. European and American practice differs with regard to the boiler capacity installed per kilowatt, which in one large American station has decreased in 12 years from 0.53 to 0.20 hp. Boilers are frequently run at over three times their rated capacity with a small drop in efficiency, but such driving is not recommended except for peak loads. The effects of steel casings, superheat, scientific methods in the boiler room and the rate of heat transfer are considered, and the results of late, unpublished experiments upon the last subject given.*

The design of the representative boilers of today is not radically different from the design of those that have been offered for twenty years past. The modern tendency toward the use of high-pressure steam has been the prime factor in causing constructional changes in boilers. Further, there is a tendency toward standardization of boiler construction by legislation. Such legislation was at first widely scattered and hardly efficient, but within the last few years there has been a general effort to pass laws governing the construction and operation of steam-generating apparatus.

A committee appointed by the American Society of Mechanical Engineers has prepared a set of rules and regulations covering the construction of steam boilers with the idea of ultimately having its recommendations adopted throughout the country. The importance of such a uniform law cannot be overestimated, as under it the users of steam boilers would be protected to an extent hitherto impossible.

Fig. 1 shows a boiler combining the stationary and marine type of Babcock & Wilcox construction. Boilers of this design are successfully used in units of 1,200 rated horsepower. The furnace is of an efficient form, and with the class of coals best suited for use on chain-grate stokers, is particularly favorable to smokeless combustion.

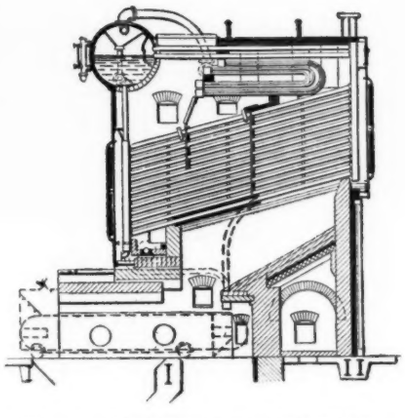


FIG. 1. COMBINED STATIONARY AND MARINE TYPE

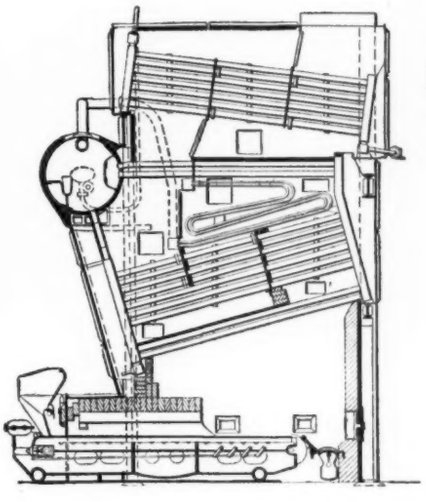


FIG. 2. CROSS-DRUM UNIT WITH INTEGRAL ECONOMIZER

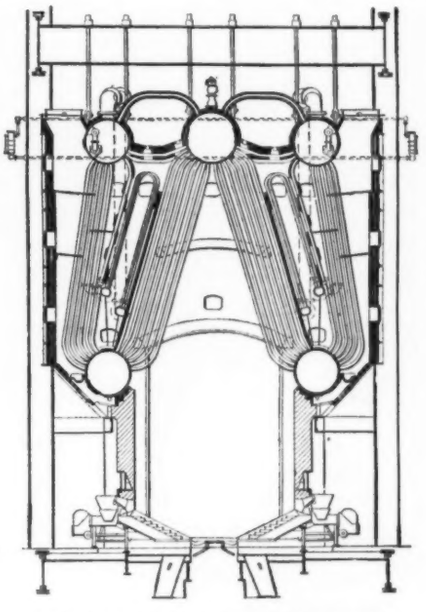


FIG. 3. DOUBLE STIRLING TYPE AS USED AT DELRAY

Fig. 2 shows a boiler that is coming into general favor in England and on the Continent. Here, too, the cross, or marine, type of drum is used. The distinctive feature of this boiler is the inclusion of an economizer as an integral part of the unit.

The boiler shown in Fig. 3 is simply the combination of two partial units of a well-known type. The distinctive feature here is the form and size of furnace made possible by the boiler design, and the good performance of these boilers is directly attributable to the furnace.

Ten years ago boiler units of 500 or 600 hp. were looked upon as approaching the practicable limits. Probably the largest units in operation today are the Stirling boilers, similar to that shown in Fig. 3, thirteen of which have been installed at the plant of the Detroit Edison Co. These boilers contain 23,600 sq.ft. of heating surface each, are nominally rated at 2,360 hp. and are developing, under ordinary operating conditions, 4,000 hp. and over.

The Commonwealth Edison Co. of Chicago has installed a number of units containing 12,200 sq.ft. of heating surface, each nominally rated at 1,220 hp., which have given good service over a long period of operation.

The increase in the size of boiler units is, perhaps, a logical result of the increase in size of generating sets, but there is an increase in the thermal efficiency of the large boiler through minimizing the radiation losses and through the higher temperatures and better mingling of the gases possible in the larger combustion chambers. From the financial standpoint, while the cost per unit of power may be no less than in small units, the saving possible in floor space, cost of setting, suspensions, valves and the like, represents a very appreciable item. That there is a considerable labor saving in the use of large units has been demonstrated in actual plant operation.

American practice differs considerably from European in respect to the number of units of a given size ordinarily allowed for a given kilowatt output, owing to the fact that in the United States ordinary rates of driving boilers are far beyond the rates ordinarily practiced in European countries.

The two most marked tendencies of modern boiler-room practice in this country are the effort to secure higher efficiencies and to obtain, from a given heating surface, higher capacities. Inasmuch as increased economies have accompanied increased capacities, these tendencies have resulted in a distinct advance in the art.

The factor having the greatest bearing on modern high efficiency is the improvement in furnace design. The heating

*Presented at Engineering Congress, San Francisco.

†Assistant to Advisory Engineer, Babcock & Wilcox Co.

surface of the properly designed boiler of today possesses the inherent ability to absorb heat economically. Under such conditions the question of boiler efficiency becomes in reality a question of economical combustion. With hand-fired furnaces it is obvious that any increase in efficiency must be due to improvement in furnace form, for the ability to properly shovel coal into a furnace cannot have changed appreciably. Naturally, with this class of firing the increase in efficiency has been relatively small.

In stoker-fired furnaces, the increase in efficiency that modern-day practice has brought about is large. This has come about from the combination of two essentials—the improvement in furnace design, and the mechanical improvement in the stoker proper as a piece of operating apparatus.

The features bringing about the possible added efficiency of the day might be summed up somewhat as follows:

### TRULY MECHANICAL FEATURES

1. A continuous and automatic fuel feed obviates the necessity of frequent openings of fire-doors. In this way the great quantities of air admitted over the fire at every firing interval in hand-fired practice are absent, and there is no deleterious effect on the boiler efficiency due to such air admission and no sudden cooling of the furnace. The result of maintaining a constant furnace temperature is obvious, both on the boiler efficiency and the life of the furnace brickwork.

2. The progressive movement of the fuel over the grates. The mechanical improvement here has in reality only to do with the actual movement of the fuel in different stages of its combustion, but closely related to this movement is the mechanical design of the apparatus, which admits the proper amount of air during the progressive combustion, the combustion—assuming proper air admission—being taken care of by proper furnace form.

This feature of proper air admission is unquestionably one of the most important factors in the bringing about of high efficiencies and primarily depends upon stoker rather than furnace design. The advantage of burning coal, or in fact any fuel, with the minimum amount of air is too thoroughly understood to need discussion here. When it is considered that with the modern stoker it is now possible to reduce the ratio of air actually supplied to that theoretically required to 1.2 to 1, the greatly increased efficiencies possible are obvious. These figures of course represent test conditions, but numerous plants are operating with a ratio of 1.4 or 1.5 to 1 where previously ratios of 2 to 1 or 3 to 1 were common in hand-fired plants.

The air admission in modern stokers of the underfeed forced-blast type is often automatically controlled by the stoker speed, giving, theoretically, the proper amount of air for different combustion rates. While the proper action of such automatic air regulation must of necessity be checked from time to time, good results are secured in ordinary practice.

With properly designed natural-draft stokers, the air is admitted in the right proportion to the different parts of the fuel bed and the total amount of air supplied for different capacities is governed by varying the draft. Much has been done in recent years in developing automatic draft regulators for regulating the furnace draft, the air admission and combustion rates.

3. The ash removal, as now accomplished in the better class of stokers, is more or less continuous and practically does away with cleaning intervals. Such intervals were formerly fairly frequent, often of considerable duration, and regardless of the efficiency secured between cleaning intervals, the great amounts of air admitted during cleaning and the consequent cooling of the furnace and setting as a whole could not but have an appreciable effect in lowering the efficiency in regular plant operation.

### THE FACTOR OF FURNACE DESIGN

The underlying principles of furnace form or design that have aided in bringing about the modern efficient furnace may be broadly summed up as follows: A form such that the volatile gases are driven from the coal before combustion proper takes place and such as to permit the air supply, properly admitted by reason of mechanical construction, to be so mingled with the volatile gases that the mixture is completely consumed before the boiler surfaces are encountered. Such a proper combustion of the volatile constituent of the coal almost automatically insures the proper combustion of the remaining combustible, assuming, of course, the proper mechanical air admission for different stages of combustion throughout the furnace. Further, such a proper combustion insures a high furnace temperature, which, assuming the proper draft conditions and correctly designed gas passage areas from the furnace, is the ultimate indication of high furnace efficiency.

Some of the factors that have had a direct bearing upon the broad plant efficiency—the cost per unit of power—are: The labor saving possible; low operating cost; low maintenance cost; the better class of labor that is gradually being employed in the boiler room (this applies not only to the actual boiler operators but to the engineers supervising the boiler-room operation); and smokeless, or rather more nearly smokeless combustion.

Another factor affecting the higher thermal efficiency now being secured, which is entirely apart from the boiler and furnace, is the use of steel boiler casing. This construction is coming more and more into use in the larger central stations.

### THE EFFECT OF STEEL CASINGS

It is rather difficult to state accurately the added efficiency due to the use of such a casing. The ordinarily accepted advantage of a boiler casing is the reduction of radiation losses. Where a steel casing is properly insulated, the saving in efficiency is made up not only of decreased radiation, but also, as compared with an ordinary brick setting that has been in use for some time, the loss due to air infiltration through the unavoidable cracks.

A steel casing alone, set over the boiler brick setting, while it would effectually prevent air leakage, would in no way reduce radiation losses, and the saving so effected would probably not warrant the cost of such an uninsulated casing. Where proper insulation is used between the brickwork and the steel casing, however, the saving warrants the expense. A properly insulated steel casing will show a saving of from ¾ to 1 per cent. over the average new brick setting. Such a casing will remain equally effective over long periods, and its saving, as compared with a brick setting that has been in service, say a year, would probably amount to 3 per cent. In modern power-plant practice, because of the severity of service, brick settings deteriorate rapidly and the cost of keeping such settings tight is considerable. Since the properly constructed steel casing preserves its insulating qualities for long periods and prevents air leakage indefinitely, the cost of upkeep of the brick setting should be credited to the steel casing in the consideration of the broad plant economy.

It is not many years ago that all boilers were rated, first, on 13 sq.ft., and then on 11½ sq.ft. of heating surface per nominal horsepower, and when a boiler developed its rated capacity, even on this basis, it was considered that all was being done that could be expected. Boiler manufacturers next rated their product on 10 sq.ft. of heating surface per nominal horsepower and in stationary boiler work this basis is used today. Such a rating is equivalent to an evaporation of 3.45 lb. of water from and at 212 deg. F. per hr. per sq.ft. of surface. In view of the evaporation per square foot of heating surface that is being secured in daily practice in thousands of plants throughout the country, there is apparently cause for the widespread agitation against such an irrational method of rating the power of boilers.

The modern tendency toward demanding more capacity from boiler heating surface is indicated by a comparison of the boiler horsepower supplied for successive generating units in use in one of the largest and most modern plants in the United States. The Commonwealth Edison Co. of Chicago installed, in 1903, the first 5,000-kw. turbine erected in this country. For this unit, which had a maximum rating of 7,500 kw., eight boilers were supplied, each containing approximately 5,000 sq.ft. of heating surface, or, on a 10-sq.ft. basis, a total of 4,000 boiler horsepower. Later, a 12,000-kw. maximum unit was installed and for its operation eight identical boilers were supplied. Still later, a 14,000-kw. machine was installed and the boiler power supplied was again a duplicate of that furnished for the 7,500-kw. set in 1903. In 1910 this company installed two 20,000-kw. machines for each of which there were supplied ten 500-hp. boiler units, or 5,000 nominal rated horsepower. In 1913 two sets were installed with maximum outputs of 20,000 and 25,000 kw. respectively. For each of these two sets four boilers containing 12,200 sq.ft. of heating surface each, or 4,880 nominal rated horsepower were supplied. In 1915 this company installed a 30,000-kw. set for which there were supplied five 1,220-hp. boiler units.

From 1903 the boiler horsepower installed per kilowatt has decreased as follows: 0.53, 0.33, 0.29, 0.25, 0.244, 0.195, 0.20.

It has long been appreciated that the capacity of a given amount of heating surface—that is, its ability to absorb heat—was limited with certain restrictions, only by the amount of fuel that could be burned under such heating surface. The amount of grate surface that can be placed under a given heating surface is limited by certain features of practicability of handling, of first cost, and of upkeep cost.

With such limitations capacity became a question of combustion rates. With the old methods of firing fuel and the limitation in size of combustion chambers, the maximum rates of combustion that could be secured were hardly comparable with what are today considered low rates. One has only to look over the boiler tests run "for capacity" of twenty years ago to appreciate this fact.

The possibility of the modern combustion rates has come only with a more thorough understanding of the relation of air supply to combustion. This contemplates not only a knowledge of the proper methods of feeding fuel to the furnace, but a knowledge of introducing the air for combustion, the proper methods of handling the gases of combustion in the furnace and of introducing them into the heating surface in the most advantageous manner. The manner of passing these gases over the heating surface in such a way as to give the maximum heat absorption is properly one of boiler rather than of furnace design, and the only changes in recent years have been not so much in design of pressure parts as in minor details of baffling.

The high rates of combustion made possible by stoker installations are attained without an appreciable loss in boiler and furnace efficiency, and, because of the proper relation of grate and furnace to the boiler heating surface, efficiencies are common in modern practice at rates of evaporation of 7 lb. per sq.ft. of heating surface per hour that were formerly not considered possible at rates of 3.5 lb. The ability of the modern stoker to burn coal economically at high combustion rates necessitates a low percentage of unburned carbon in the ash. When stokers were first introduced it was no unusual thing for the ash discharged to show at least 40 or 60 per cent. of unburned carbon. In power-plant practice today many properly operated stokers are showing less than 20 to 30 per cent. unburned carbon in the ash at high rates of combustion, a figure which compares favorably with the best class of hand-firing at combustion rates such as to give only low capacities from a boiler.

## THE USE OF MECHANICAL STOKERS

It should not be implied from the foregoing that the stoker-fired furnace is the universal cure-all for boiler ills. There are numberless cases where the installation of a stoker is in no way warranted. If coal- and ash-handling machinery is not installed in connection with the stoker, the advantages resulting from the automatic feeding of the fuel to the furnace are largely lost. In small plants, as in temporary installations, the cost of coal- and ash-handling apparatus is not justifiable, and stokers are permissible, perhaps, only where the question of smoke is paramount.

Furthermore, there is no stoker that will satisfactorily handle all classes of coal and, in fact, there are some coals that can be burned with reasonable success in hand-fired furnaces that cannot be handled by any stoker manufactured today. In making a selection of stokers, it is important that the type be chosen that has been shown, in actual practice, to give the best results with the particular class of coal to be burned. While stokers are largely automatic in their operation, it is to be remembered that they require more expert attention than do hand-fired furnaces. Stoker first cost and upkeep cost are higher than with hand-fired furnaces. The upkeep cost of the furnace brickwork, too, is greater, because of the more severe furnace conditions. So many factors enter into the problem that each individual set of conditions must be considered by itself, and the advantages due to increased efficiency and greater capacity without loss of efficiency of stoker-firing over hand-firing, must be balanced against cost, operating expense, and the like, before it can be determined that one or the other method is preferable.

The references that have been made to capacity have been in connection with stoker-fired coal furnaces. Higher capacities are being secured, too, in hand-fired furnaces, but the cause here is almost entirely the improvement in furnace design, as the ability to shovel coal by hand has not increased appreciably. Hand-fired capacities are limited by the ability of the fireman, draft and the like, and it is rarely that capacities of over 150 per cent. are secured for any but peaks of short duration.

The same improvements in boiler furnace practice, mechanical and of form, which have made possible both greater capacities and high efficiencies, have enabled the modern boiler to meet three constantly recurring conditions in plant operation with infinitely better results, from the standpoint of broad economy, than formerly.

First, the ability of a boiler to be placed on the line quickly, either from a condition of bank or from a cold boiler. Second, the ability of a boiler or boiler plant to handle widely varying and rapidly fluctuating loads without appreciable variation in efficiency. Third, the ability of a boiler to carry continuous high overloads without an excessive drop in efficiency.

## TIME REQUIRED TO START BOILERS

In a standby plant equipped with 640 rated horsepower boiler units, it is customary to carry the fires on bank, never letting the steam pressure fall to a point 10 lb. lower than the working pressure, the fires being held in such condition that they may be broken up at a moment's notice. Under such conditions a boiler which had been on bank for 24 hr. could deliver steam at the rate of 20,000 lb. per hr., or approximately its rated capacity, three minutes after the ash-doors and damper were opened and fires broken up; and three minutes later it was delivering steam at the rate of 50,000 lb. per hr., or 260 per cent. of its rated capacity. In this plant the boilers, when called upon to take up the load, are capable of delivering their maximum capacity before the turbines are up to speed.

In this same plant some tests were run in bringing up a cold boiler and cutting it into the line. With a temperature of water in the boiler of 150 deg. (there had been no fire in this boiler for 48 hr.), it was cut into the line at 172 lb. gage pressure in 51 min. and 20 sec. after the fires were started. In 5 min. and 10 sec. after cutting in, the boiler was delivering steam at the rate of 35,000 lb. per hr., or 180 per cent. of its rated capacity.

Considering the difference in stationary- and marine-boiler design, these figures compare favorably with what is secured in marine practice. In this class of work the record for getting up steam from a cold boiler quickly is held by one of the boilers of the U. S. S.S. "Cincinnati." From a temperature within the boiler of 72 deg., steam was raised here to 215 lb. in 12 min. and 40 sec.

In a plant burning oil fuel, a similar test was run on a boiler of 640 nominal rated horsepower. The temperature of the water in this boiler, which had stood for 50 hr. with all doors and dampers open to cool the setting, was 122 deg. The boiler was cut into the line at 175 lb. pressure 26 min. and 30 sec. after lighting the oil fires, and 6 min. after

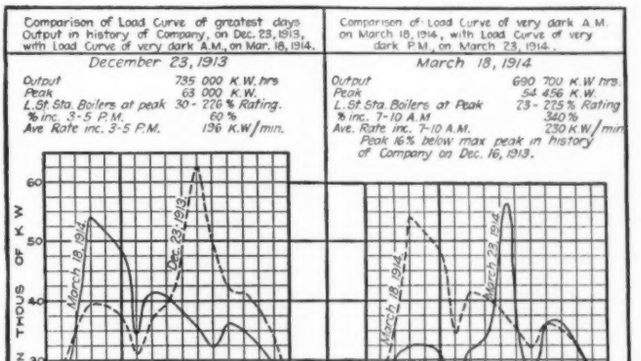

Comparison of Load Curve of greatest days Output in history of Company, on Dec. 23, 1913, with Load Curve of very dark A.M., on Mar. 18, 1914.
December 23, 1913
Output 735 000 K.W. hrs
Peak 63 000 K.W.
L.St.Sta. Boilers at peak 30 - 276 % Rating.
% inc. 3-5 P.M. 60 %
Ave Rate inc. 3-5 P.M. 196 K.W./min.
Comparison of Load Curve of very dark A.M. on March 18, 1914, with Load Curve of very dark P.M., on March 23, 1914.
March 18, 1914
Output 690 700 K.W. hrs.
Peak 54 456 K.W.
L.St.Sta. Boilers at Peak 23 - 225 % Rating
% inc. 7-10 A.M 340 %
Ave. Rate inc. 7-10 A.M. 230 K.W./min
Peak 16% below max peak in history of Company on Dec. 16, 1913.
LOAD IN THOUS OF K.W
March 18, 1914
Dec. 23, 1913
March 23, 1914
A.M.
P.M.
TIME
Greatest drop in steam at any time on Mar. 23, 1914 - 10 lbs. No batteries called upon.
Street Lights on at 4.07 P.M., off at 4.23 A.M.
Mar. 23, 1914
Output 619 200 K.W. hrs.
Peak 50 835 K.W.
L.St.Sta. Boilers at Peak 23 - 243 % Rating.
% inc. 3-4.15 P.M. 68 %
Aveg. Rate inc. 3-4.15 P.M. 307 K.W./min.
L.St.Sta. Rate inc. 3.55 P.M. 1 000 K.W./min.
L.St.Sta. Rate inc. 3.45-4.15 P.M. 450 K.W./min.
Peak 11% below max. peak in history of Co., on Dec. 16, 1913.
Note:- Curves show combined K.W. delivered to bus.

FIG. 4. TWO UNUSUAL DAY-LOAD CURVES

cutting in was delivering steam at the rate of 50,000 lb. per hr., or 260 per cent. of its nominal rating.

The construction of the modern stoker is such that the rate of fuel fed can be altered almost instantaneously and the draft conditions altered to meet rapid changes in the required combustion rates. The furnace form is such that the products of combustion are handled efficiently, almost regardless of the changes in their volume. The result is not only the ability of the plant to handle such loads, but to handle them without material losses in thermal efficiencies of individual units. Widely varying loads are carried today in ordinary plant operation with overall efficiencies higher than those formerly secured for constant loads and test conditions.

Fig. 4 shows two day-load curves at the plant of the Edison Electric Illuminating Co. of Boston. While perhaps these loads are unusual, they are representative of the fluctuations that are encountered in hundreds of plants throughout the country under certain conditions. Considering that of Mar. 23, 1914: At 1 o'clock the boilers on the line (23 in

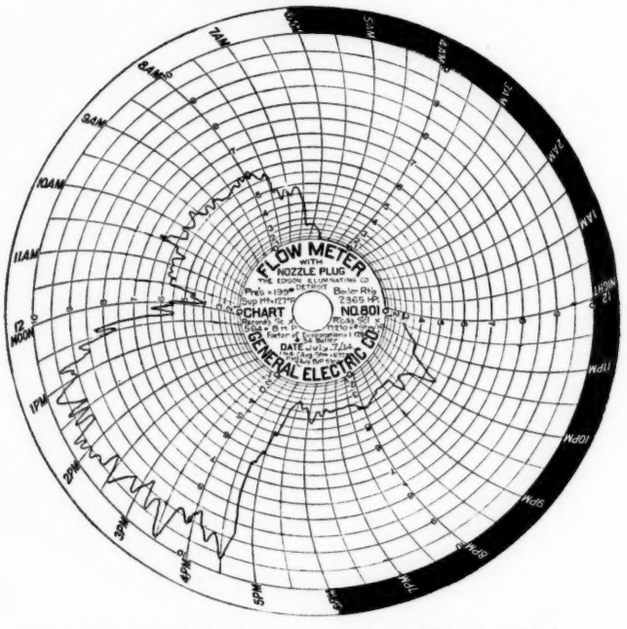



FIG. 5. RECORD OF OVERLOAD OPERATION

number) were operating at about 110 per cent. of their rated capacity; at 3:30, at 155 per cent.; at 4:15, the peak was reached, or 243 per cent. of the rated capacity of the boilers. The load had decreased again at 5 o'clock to 155 per cent. of the boilers' rated capacity. It is of particular interest to note that during this peak no additional boilers were cut into the line and that the steam pressure at no time fell more than 10 lb. below the maximum.

There are plants throughout the country in which boilers are developing, during periods of peak loads, capacities of 300 per cent. of the rated load and above. The central-station operator fully appreciates that such high overloads are desirable only over short periods, and would not contemplate such capacities for average or continuous operation. The small-plant operator, on the other hand, seeing reports of these capacities, because he does not distinguish between peak-load and average operating capacities sees no reason why his boilers should not be operated at similar rates.

It is questionable whether there are twenty plants throughout the country operating continuously, day in and day out, at capacities of 175 per cent. of the rated load or over. The figures published from time to time that show capacities of over 250 or 300 per cent. of the rated load are ordinarily figures secured on tests that have been run to show what boilers are capable of doing during peak loads and not with the idea that these are the continuous operating capacities of the boilers. The interesting fact in these high-capacity figures, apart from an indication of what the modern boiler can do, is that during peaks the efficiency remains relatively high at ratings from 200 to 300 per cent.

In two tests of the Detroit Edison Co.'s large boiler units, of 24 and 26½ hr. duration, capacities of 196 and 211 per cent. of the boiler's rating were secured, with efficiencies of 75.6 and 75.8 respectively. It is interesting to note that in these tests, 18 in number, over a range of from 80 to 211 per cent. of normal capacity, the variation in efficiency was all within a range of 5.6 per cent.

In two 10-hr. tests of a 500-hp. unit, capacities of 253 and 316 per cent. were secured, with efficiencies of 69.4 and 67.6 per cent. respectively.

In a test of 5 hours' duration of a 500-hp. unit, a capacity of 300 per cent. was obtained, with an efficiency of 69.7 per cent.

Fig. 5 is interesting to show the ability of the modern boiler to carry high overloads. From this chart, between 8 a.m. and 11:30 the boiler is developing 3,240 hp., or 137 per cent. of its rated capacity. From 12 o'clock until 1 o'clock, the load increases to 5,076 hp., or 214 per cent. of the boiler's rated capacity. Between 1 o'clock and 4:30, the boiler is delivering an average of 5,300 hp., or 224 per cent. of its rated capacity, and during this period the efficiency was over 70 per cent.

## THE MOST ECONOMICAL RATE OF STEAMING

In view of the possible overloads, as indicated by the figures given, the question arises as to the capacity at which a boiler plant should be run to show the highest operating efficiency. The governing factors here are so numerous that only the most general statement may be made. The ability of individual units to be operated at very high capacities over periods of peak load has been shown, and in speaking of practicable operating capacities, it is intended to consider the average load advisable.

Primarily, the controlling factor in determining the number of boiler units that should be installed, regardless of the nature of the load, is the ability to carry the maximum load that may be thrown on the plant under any conditions.

The consensus of engineering opinion respecting the best operating capacities for boilers is somewhat as follows:

For a constant 24-hr. load, the operating capacity, to give the highest overall plant economy, is between 125 and 150 per cent. of the boiler's normal rating.

For the more or less constant 10- or 12-hr. a day load, where the boilers are placed on bank at night, the point of maximum economy will be somewhat higher, probably between 150 and 175 per cent. of the boiler's rated capacity.

The third class of load is the variable 24-hr. load found in central-station work. Here, even more than with the other classes of loads, the statement as to the economical point of operation must be general, owing to the variation in handling, with differences in fuel, labor, type of stoker, flexibility of operation of the boiler and furnace, and other factors.

Modern methods of handling loads of this description, to give the best operating results under different conditions of installation, are as follows:

1. The load on the plant at any time is carried by the minimum number of boilers that will supply the power necessary, operating these boilers at capacities of 150 to 200 per cent. of their normal rating. There is, perhaps, an increasing tendency toward the higher figure. Such boilers as are in service are operated continuously at these capacities, the variation in load being cared for by varying the number of boilers on the line, starting up boilers from a banked condition during peak-load periods and banking them after such periods. This is, perhaps, at present the most general method of central-station operation.

2. The variation in the load on the plant is handled by varying the capacities at which a given number of boilers are run. At low plant loads the boilers are operated somewhat below their normal rating, and during peak loads, at their maximum capacity. The ability of the modern boiler to operate over wide ranges of capacities without appreciable loss in efficiency has made such a method practicable.

3. The third method of handling the modern central-station load is, perhaps, only practicable in large stations or groups of interconnected stations. Under this method the plant is divided into two parts. What may be considered the constant load of the system is carried by one portion of the plant, operating at its point of maximum economy. Owing to the possibility of very high overall efficiencies at high boiler capacities where the load is constant, where the grate and combustion chamber are designed for a point of maximum economy at such capacities, and where there are installed economizers and such apparatus as will tend to increase the efficiency, the capacity at which this portion of the plant is today operated will be considerably above the 150 per cent. given as the point of highest economy for the steady 24-hr. load for boilers without economizers.

The variable portion of the load on a plant so operated is carried by the second division of the plant under either of the methods of operation just given.

Apart from the question of furnace and stoker design, there are three factors that have an important bearing on the determination of the point of maximum continuous overload.

The first of these factors is feed water. Where high boiler overloads are either expected or required, it is essential that the feed water be free from scale-forming ingredients and matter that might tend to cause foaming or priming. While the design of the boiler plays a part here, in that certain boilers at high capacities will handle without difficulties waters that cannot be handled with other boilers, the water itself is the more important factor in any boiler.

The second factor is furnace brickwork. With the increased combustion rates of modern practice and the higher furnace temperatures of the present-day furnace, the condi-

tions which the brickwork of the furnace is called upon to withstand are much more severe than in former practice. Fortunately, progress in the art of brick manufacture has accompanied the movement toward higher capacities, and firebrick as manufactured today, when properly installed, are able to withstand, over considerable periods and under practically all conditions of service, temperatures and variations in temperatures that some fifteen years ago were not practicable from the standpoint of furnace upkeep cost.

The third factor is that of draft—draft not as affecting combustion rates, but in its connection with the life of the brickwork setting, particularly the furnace brickwork.

### CHIMNEYS ARE STILL NECESSARY

Many of the successful stokers of today are utilizing a forced draft for their operation. At one time it was assumed that this class of stoker did away with the necessity of a stack, except for carrying off the gases of combustion. As combustion rates increased, however, and it was necessary to supply more and more blast, it became evident that, from the standpoint of protection to furnace brickwork, a draft suction was necessary as well as a blast. In view of the enormous heat now developed in stoker-fired furnaces and the great weight of the gas passing over the boiler-heating surfaces, it is now generally accepted that some means must be provided, whether by natural or induced draft, to remove these gases from the furnace promptly in order to prevent a "soaking up" action of the heat by the furnace brickwork. To assure such removal, the means provided should be such as to give a draft suction throughout all parts of the setting under any conditions of service.

### USE OF FUELS OTHER THAN COAL

With oil fuel, assuming a properly designed boiler, the furnace form and the methods employed for introducing air for combustion are of the utmost importance. Experience has shown that the furnace design with which the best results are secured is one in which the oil is introduced into the furnace in the direction in which it increases in height. This increase in furnace volume in the direction of the flame insures free expansion, a thorough mixture of the oil with the air, and the consequent complete combustion of the gases before the boiler-heating surfaces are encountered. Under operating conditions it is possible to run with a ratio of actual air supplied to that theoretically required of 1.25 to 1.

The tests run at Redondo a number of years ago in one of the Pacific Light and Power Co.'s plants probably still hold the record of high efficiency, and that this efficiency was over 83 per cent. gross clearly indicates what may be accomplished with this fuel. Many plants are operating continuously at a gross efficiency above 76 per cent.

In stationary-boiler practice steam atomizing burners are in general use, and much has been done within the last few years to reduce the steam consumption of the apparatus. At Redondo, in the test to which reference has been made, the steam used by the burners was approximately 2 per cent. of the total generated, giving, for a gross efficiency of 83 per cent., a net efficiency of 81 per cent. Refinement in burner design has made possible today a steam consumption by the burners of as low as 1 per cent.

Oil-fired stationary boilers are being operated at overloads nearly as high as are coal-fired boilers and with a falling off in efficiency probably not as great. The record for capacity with oil firing was secured on a marine boiler where an evaporation from and at 212 deg. per sq.ft. of heating surface, of 18.7 lb. was secured. On the ordinary basis of rating stationary boilers, this would be 540 per cent. of rating. This capacity was secured with an efficiency of 78 per cent. These figures represent capacities considerably higher than have been obtained with stationary boilers.

The fact that boilers are being operated at over 200 per cent. of their rating with wood refuse containing over 40 per cent. of moisture indicates how satisfactory the improvements in wood-burning furnace design have been.

On sugar plantations today, bagasse, instead of being an auxiliary fuel, is burned so efficiently that in many instances no other fuel is required to operate the entire mill.

Of the gaseous fuels used today probably the most common is blast-furnace gas. Here, as with wood refuse, capacity rather than economy was the object until recent years. Capacities of 175 to 200 per cent. are being developed in numerous steel plants with this fuel.

For years it was considered impracticable to make use of waste gases for the generation of steam where the temperature was below 1,800 deg. F. Within the last two years there has been a considerable revision of ideas in the utilization of waste heat. Perhaps the most important feature of the change in attitude toward waste-heat utilization is the present practicability of using gases of low temperatures. A few examples of what is actually being accomplished will best serve to illustrate this fact.

The lowest-temperature gases with which a waste-heat boiler installation has as yet been found practicable are probably those from the modern openhearth steel furnace. These temperatures run from 950 deg. F. to 1,400 and average approximately 1,150 deg.

From a boiler containing 3,600 sq.ft. of heating surface with an entering gas temperature of 1,153 deg., 200 boiler horsepower has been secured as an average for a week's run. This represents approximately 60 per cent. of the boiler's rated capacity. The openhearth furnace to which this boiler was attached is rated at 35 tons. From a second boiler installed in connection with a 75-ton openhearth furnace, with an entering temperature of 1,360 deg., 426 boiler horsepower was obtained from 5,230 sq.ft. of heating surface in a test of 159 hr.

When it is considered that these gases have hitherto been discharged to the atmosphere, the saving in plant operation is obvious. The steel companies ordinarily value a boiler horsepower at $40 a year, and the return on the investment represented in the complete boiler, fan and connecting flue installation has proven to be between 60 and 70 per cent. The net saving in manufacturing cost is in the neighborhood of 20c per ton of steel produced.

Aside from the utilization of low-temperature waste gases, great progress has been made, using the same basis of high gas velocity, in the use of waste heat having temperatures that approach those found in coal-fired practice. An example of this class of work is found in beehive coke-oven plants where the temperature of the gas runs from 2,000 to 2,300 deg. F.

A boiler containing 10,000 sq.ft. of heating surface, installed in connection with several batteries of beehive coke ovens, developed in an 8-hr. test 1,960 hp., or 196 per cent. of its normal rated capacity. This capacity, of course, is a function of the volume of gas passing as well as of the velocity. The interesting feature of this result is that, with an entering gas temperature of 2,158 deg., the exit temperature was 477 deg., interesting either when compared with coal-fired practice for such overloads or for former practice with this class of waste gas. An installation made some ten years ago, with beehive coke ovens of approximately the same size and number, showed an exit gas temperature of 800 deg. For the same volume of gas passing through the boiler as was utilized in developing the 1,960 hp., the same entering temperature, and an exit temperature of 800 deg. as against 477 deg., the horsepower developed would be 1,577 as against 1,956, or an increase, for the modern waste-heat boiler in this particular class of work, of 24 per cent.

### USE OF SCIENTIFIC METHODS IN THE BOILER ROOM

Unquestionably, there is no one factor that has had as beneficial an effect in the securing of modern-day boiler-room results as the intelligent supervision of this portion of the steam plant, and nowhere has the efficiency engineer had such a chance to show improved performance. This supervision has come with the full realization of the wide difference existing in the results that were formerly secured in everyday practice and those theoretically possible.

For this supervision a full knowledge is necessary, not only of what a plant can do under the best operating conditions, but also of what a plant will do under any and all of the conditions that may arise. The former knowledge is secured by a systematic testing; the latter by continuous records so arranged that the results may be directly compared for any period or any set of conditions.

The continuous records serve as a check on plant losses, and as the size of a plant increases such a check becomes a necessity. In a large plant, a saving of but a fraction of 1 per cent. in the fuel bill represents an amount running into thousands of dollars annually, while the expense of supervision is relatively small. The methods of supervision in a large plant are naturally elaborate and complete. In the smaller plant, the same methods are followed on a more moderate scale with a corresponding saving in fuel and without an appreciable increase in plant organization or expense.

Improvements in modern recording apparatus have led to reliability and accuracy and are of great service in attaining proper operating results. Records of water evaporated and the fuel consumption are of primary importance. Other records of temperature, gas analyses, draft and the like, serve as a check on the fuel consumption. They permit an intelligent study of the distribution of losses and afford a means of remedying such losses where improvement is possible.

The boilers of the modern power plant are almost universally equipped with integral superheaters. Superheaters as

now offered have been in common use in stationary boilers for some twenty years, and during that time, as in the case of the modern boiler, there have been no radical changes in design.

Following Hirn's experiments of 1857 and Isherwood's in 1862-64, there was a marked interest on the part of engineers in the use of superheated steam. By the late '60s, practically all marine boilers were equipped with superheaters, and while in stationary practice their use was more limited, numerous installations were made. The designs were many, but all were alike in location, namely, in the uptake of a boiler. During this period, all boilers were operated under working

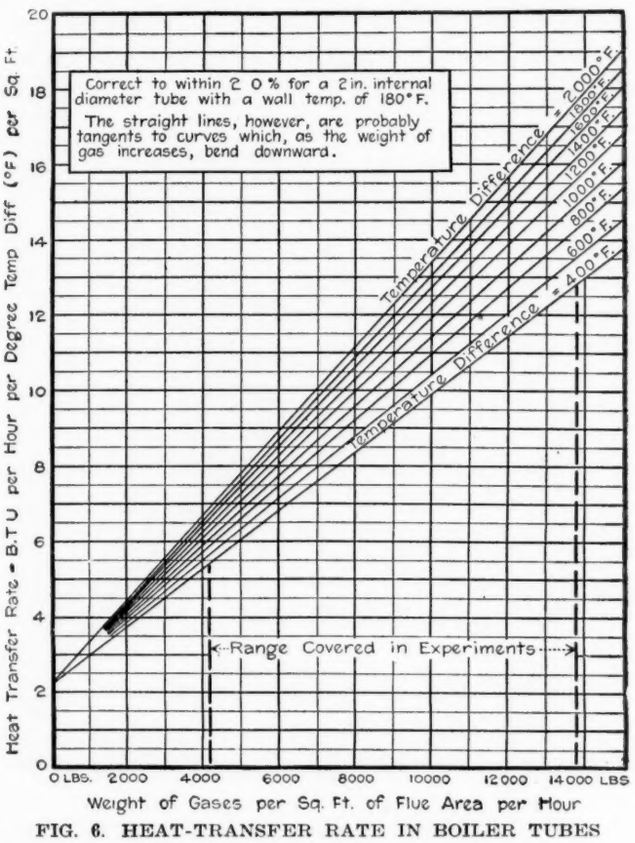

Correct to within 2 0 % for a 2 in. internal diameter tube with a wall temp. of 180° F.
The straight lines, however, are probably tangents to curves which, as the weight of gas increases, bend downward.
Temperature Difference = 2000° F.
1800° F.
1600° F.
1400° F.
1200° F.
1000° F.
800° F.
600° F.
Temperature Difference = 400° F.
Range Covered in Experiments
Heat Transfer Rate - B.T.U. per Hour per Degree Temp Diff (°F.) per Sq. Ft.
0 LBS. 2000 4000 6000 8000 10000 12000 14000 LBS
Weight of Gases per Sq. Ft. of Flue Area per Hour

FIG. 6. HEAT-TRANSFER RATE IN BOILER TUBES

pressures of less than 50 lb., and 100 deg. of superheat with such pressures represented ultimate temperatures that could in no way be considered high.

The introduction of compound engines and the use of high-pressure steam in the late '60s and early '70s combined to force the superheater temporarily out of the field. Such engines and high-pressure steam showed an increase in efficiency over simple engines and the low-pressure steam that had been in vogue, considerably greater than that obtained by simply superheating the low-pressure steam. With the increased temperature due to higher pressures, it was found where attempts were made to superheat the steam to as great a degree as formerly, that difficulties were encountered in lubrication, and where superheat was used it was necessary to reduce the amount to a point where the gain secured did not warrant the expense of an installation.

How completely the use of superheaters was abandoned during this period is shown by a quotation from Seaton's "A Manual of Marine Engineering," appearing in editions as late as 1890: "The use of superheated steam has been discontinued since the pressure has gone beyond 60 lb. per sq.in., partly in consequence of the increase in temperature beyond that due to the pressure being prejudicial to the good working of certain parts, partly also due to the danger and inconvenience of the superheater itself, and not a little to the action taken by the Board of Trade (British) with respect to it." In view of the present-day knowledge of the properties of superheated steam, the Board of Trade's attitude referred to is of interest. This body took a strong stand against the installation of superheaters on the ground that the steam at high temperatures might break into its constituent elements with results that would be dangerous.

During this period, while the general interest in the use of superheated steam was apparently lost, certain engineers, prominent among whom were Hirn, Schwoerer, Schröter and Wilhelm Schmidt, continued to investigate and experiment. In 1895 Professor Schröter conducted a series of tests of a boiler and engine especially designed and built for use with superheated steam by Doctor Schmidt. The published results of these tests, showing as they did efficiencies which at the time were remarkable, re-aroused interest in the use of superheated steam, and a number of Schmidt engines and superheaters were installed. This interest spread, particularly in Europe, and numerous designs of superheaters were placed upon the market within a few years after Schmidt's experiments. The first superheaters in this country were commercially marketed in 1898. From that time their use has increased enormously until, as stated, the boiler of today is almost universally equipped with an integral superheater.

Experience has shown that for efficient operation, the modern superheater must meet certain requirements that may be summed up as follows:

Superheaters must be located in the direct path of the gases as they sweep over the boiler-heating surface; that is, the gases utilized for the generation of steam must also be utilized to superheat that steam.

The location must be such that the full superheating surface is presented for contact with the gases, but the arrangement of surface must cause no undue amount of frictional resistance to the gases in their passage.

The surface should offer the least opportunity for the adhesion of soot and dust.

All parts of the superheater should be readily accessible for inspection and repair, and the design should be such as to allow freedom of expansion without affecting the boiler proper or the setting.

All superheaters should be equipped with safety valves set somewhat lower than the boiler valves. This is necessary in order to insure a flow of steam through the superheaters when the load is suddenly taken from the boiler.

Practically all of the modern superheaters meet these requirements to a greater or less degree. In performing their function they interfere in no way with the operation of the boiler, and their upkeep cost is negligible. The efficiency of a boiler equipped with an integral superheater is greater than that of one in which no superheater is installed, but the added efficiency due to the superheater is difficult to determine.

For some years after the re-introduction of the use of superheated steam, there was a tendency on the part of steam users to demand degrees of superheat as high as could be obtained from integral superheaters. The use of such high temperatures led to a number of operating difficulties and particularly to trouble with the cast-iron fittings in general use. These difficulties led to a decided reduction in the amount of superheat desired, and over the period of 1905-12 the average degree of superheat, throughout this country at least, was probably considerably below 150 deg. Operating difficulties, however, were gradually overcome, turbines largely replaced reciprocating engines, and engineering opinion came to an agreement that steel fittings should replace cast-iron for superheated steam practice. Under the improved modern plant conditions there seems to be, within the past two years, a strong tendency on the part of engineers toward the use of degrees of superheat considerably in excess of 150.

There have just been completed, under the direction of J. E. Bell, an extensive and remarkably comprehensive set of experiments on "Heat Transfer Rates." The apparatus used consisted of a 2-in. internal diameter copper pipe, surrounded by 20 individual water jackets each 1 ft. long. The gases were drawn from an illuminating-gas furnace in which temperatures above 2,600 deg. could be obtained. The range of gas-flow rate covered was from 4,000 to 14,000 lb. per hr. per sq.ft. of cross-sectional area of passage. The difference in temperature between the gas and metal surface was from 400 to 2,000 deg. F. The temperature of the metal surface varied from 145 to 215 deg. F., the average wall temperature being 180 deg. The variation in specific heat of the gases was taken into account.

The flue gases, after leaving the experimental tube were cooled in a 2-in. coil 26 ft. long, surrounded by water. The gases leaving the coil were passed through a box where the dew point was determined. The dew point, together with the entering and exit temperatures of the gas and water through the cooler and the flue-gas analyses taken during the tests, gave the most accurate method of determining gas weights.

The rate of heat transfer may be expressed by the formula,

$$R = A + B\left(\frac{W}{a}\right)$$

where

R = The rate of heat transfer;

A = A constant;

B = A function of the temperature difference;

$\frac{W}{a}$ = The rate of mass flow per unit area of channel.

The value of A as determined by these experiments is 2.20. The value of B varies with changes in the temperature difference from 0.000770 for a temperature difference of 400 deg. F. to 0.001120 for a temperature difference of 2,000 deg. F. These values of B may be readily obtained from the chart for any rate of gas flow and any temperature difference.

Fig. 6 gives in graphic form the results of these experiments.

It is interesting to note that while at high rates of gas flow the temperature difference has an important bearing on the heat-transfer rate, at low weights of gas flow, such as are encountered in boiler practice, the effect of the temperature difference is relatively small.

## Work of Canadian Hydro-Electric Commission

In a paper on "Electric Power in Canadian Industry" presented at the International Engineering Congress, Charles H. Mitchell devoted considerable space to the work of the Hydro-Electric Commission of Ontario. This Commission has created world-wide interest as an experiment in publicly owned power, and its history and the results of the undertaking deserve the fullest consideration in dealing with electric power in Canadian industry.

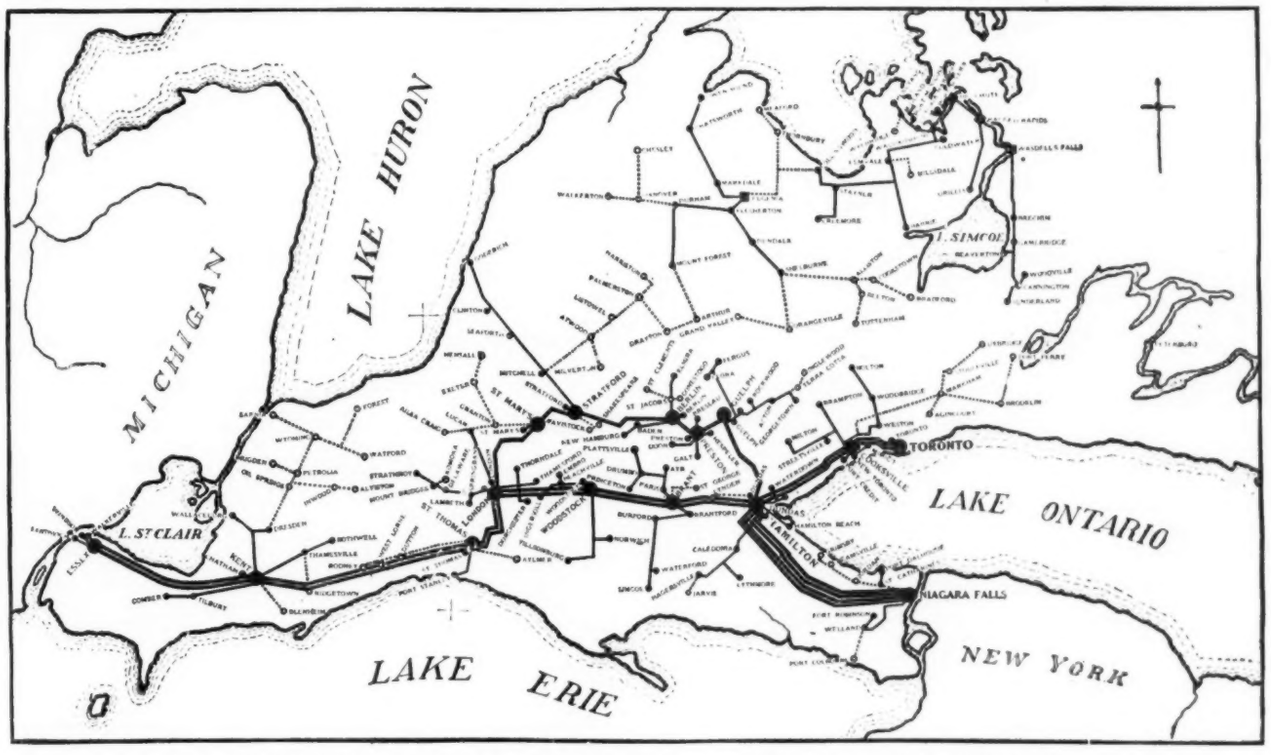
For some years previous to 1906 citizens of central southwestern Ontario had endeavored to secure a working basis for a comprehensive scheme of supplying power to various municipalities, the City of Toronto comprising the largest interest in the matter. In 1906 the Provincial Government created a commission empowered to investigate power conditions in the province, and a further commission was established after the rendering of the preliminary report, which resulted in bylaws on the question of power supply being voted upon by the interested municipalities, and an agreement was entered into by these cities and towns with the Hydro-Electric Power Commission of Ontario for a supply of electric power to be transmitted from Niagara Falls. For the carrying out of the necessary work the commission is empowered to make expenditures which are repayable by the municipal corporations that have entered into the contract.

The price per horsepower-year that each municipality has to pay is the cost of the electricity to the commission plus interest at 4 per cent. upon the moneys expended, an annual sum sufficient to form in thirty years a sinking fund for the retirement of the securities issued by the province; and line loss and the cost of operating, maintaining, repairing, renewing and insuring the work. The amounts payable are annually adjusted and apportioned.

Tenders were called for the supply of electric power from Niagara Falls, and in March, 1908, the commission entered into a contract with the Ontario Power Co. for amounts up to 100,000 hp. Power was obtained from this source at $9.40 per hp. per yr. for amounts up to 25,000 hp., and when the demand should exceed 25,000 hp. the price was to become $9 per hp. per yr. This price is for 12,000-volt three-phase 25-cycle power delivered to the commission's transformer station at Niagara Falls.

In addition to the district served in the Niagara system, the commission buys power from the Kaministiquia Power Co., of Fort William, and sells to the City of Port Arthur; from the Ottawa and Hull Light and Power Co., selling to the City of Ottawa; from the Auburn Power Co., selling to the City of Peterborough; and from the New York and Ontario Power Co. for selling to the group of towns in the St. Lawrence system. Further, the commission purchased the generating and distribution sysem of the Simcoe Railway and Power Co. at Big Chute on the Severn River and made considerable extensions to the distribution system, this plant being arranged to tie in with a generating plant at Eugenia Falls. A generating station and distribution system has just been completed at Wasdell's Falls, and the commission is at present engaged on preliminaries to construction of radial electric railroads in the vicinity of Toronto and has also undertaken the engineering and construction of the electrification work of the London & Port Stanley Ry.

The map shows the extent of this distribution area served by the commission, exclusive of the Port Arthur, Ottawa and St. Lawrence systems. The transmission lines aggregate 395.7 mi. of double-circuit 110,000-volt line, 37 mi. of single-circuit 110,000-volt line, 722 mi. of single- and double-circuit pole lines of voltages from 13,200 to 46,000, and 77 mi. of low-voltage circuits.




MAP SHOWING TERRITORY SERVED BY THE HYDRO-ELECTRIC COMMISSION

The municipalities originally included in the power agreement numbered 15; the number has since increased to 82. At the beginning of the present year over 96,000 customers were served by the system and the power purchased by the commission was approximately 100,000 hp.

The commission recommends the rate to be applied by the municipality for consumers, and the municipalities in general adopt them. The rates are now on a uniform basis and involve a service charge which in the case of power consists of a flat rate of $1, a special rate of approximately 12 times the standard rate for the first 50 hr. of service each month,

and of approximately 8 times the standard rate for the second 50 hr. of service each month; the balance being at a standard rate per kilowatt-hour. Domestic-lighting rates bear a service charge of 3 or 4c. per 100 sq.ft. of floor area per month, and a standard rate of from 2.5 to 7c. per kw.-hr. Commercial-lighting rates in general have a service charge, involving the first 30 hr. per month and a standard rate for all additional time. Discounts for prompt payment apply throughout. The average rate paid for domestic service is calculated to be about 3.7c. per kw.-hr. Street-lighting rates are in general flat rates applied to the particular type of lighting unit served in each respective municipality.

Power is bought from the Ontario Power Co. on a 20-min. peak basis and is taken by the municipalities in a similar manner. The oversale of power by the commission, resulting from the time distribution of the respective superimposing pay peaks, is quite an appreciable amount and is in excess of the line and transformer losses. This has justified the commission in excluding loss cost from power rates. The flattening of the load carried, however, over the 24-hr. period is gradually reducing the oversale.

## PERSONALS

James Cole Roberts, of the United States Bureau of Mines, Denver, Colo., has been elected by the board of trustees of the Colorado State School of Mines to the Joseph Austin Holmes professorship of safety and efficiency engineering.

## ENGINEERING AFFAIRS

**The Society of Naval Architects and Marine Engineers** will hold its 23rd general meeting at the Engineering Societies Building, New York City, on Thursday and Friday, Nov. 18 and 19.

**Ohio Society of Mechanical, Electrical and Steam Engineers** will hold its annual meeting and election of officers at Zanesville, Ohio, Nov. 18 and 19. Papers will be presented on "Advertising, Its Influence on Engineering," "Powdered Coal," "Monel Metal," "Smokeless Boiler Design," "Soot," "Steam Traps" and "A Heating System."

**Detroit Engineering Society.**—J. C. McCabe, boiler inspector of the city of Detroit, and a member of that society, presented a paper to the Detroit Engineering Society on Friday evening, Nov. 5, upon "The Diagnostics of Steam Boiler Ailments." The paper dealt with difficulties encountered in obtaining uniform boiler plates from the mills, stresses set up in shaping boiler plates, deformation of plates in boilers in operation, due to overheating, formula to determine approximate temperature at which deformation will occur in any boiler with given pressure, behavior of boiler tubes in various types of water-tube boilers (shown by diagrams), curves showing properties of boiler material under various temperatures, explanation of causes of some well-known boiler explosions. The paper was illustrated by numerous lantern slides.

## NEW PUBLICATIONS

STEAM BOILER ECONOMY. By William Kent. Second Edition. Published by John Wiley & Sons, Inc., New York City. Cloth; 6x9 in.; 717 pages; 287 illustrations; numerous tables. Price, $4.

The first edition of this book was published fourteen years ago, and in the interval from then until now remarkable progress has been made in boiler operation. In that first edition the well-known author covered the subject most commendably in 458 pages of the same size and type matter as used in this second edition, which has 717 pages. As most of the additional matter is related to recent progress in the art, these 259 more pages are a good "stick" by which to measure.

In the preface the author says, in part, "Boilers are now driven in electric power stations at double their former rate, with high fuel economy and with decreased cost of labor and maintenance." If the cost of maintenance is here related to output of the boiler, the statement is acceptable; but if related to time, it is not; for with the high ratings now practiced and because of the extremely high furnace temperatures, boiler maintenance as related to time is indeed far higher than under low-rating conditions.

Engineers are so familiar with this book—that is, the first edition—that the last three paragraphs of the author's preface to the new edition serve as well as anything that might be written to acquaint one with the additions. After mentioning the various improvements and giving a brief statement of the results effected by each, he says:

In the present edition all of these several improvements are discussed at length. Numerous records of recent tests of different kinds of boilers are given, showing the efficiency that may be obtained with different coals under different conditions of operation.

The author's formula, given in Chapter IX, showing the relation that exists between boiler efficiency, the rate of driving, the air supply and other variables that have a relation to efficiency, has been developed so as to show the effect of imperfect combustion and of moisture in coal, and a new straight-line formula for efficiency, assuming complete combustion, and plotted diagrams made from it have been devised, enabling the user to predict the maximum economy that can be obtained with different rates of driving and different proportions of air supply. New tables of analyses and heating values of American coals are given, and the chapters on "Coal Fields of the United States" and "Heating Values of Coal" have been revised.

Two new chapters have been added, one on "Boiler Design and Construction" and one on "Boiler Attachments and Boiler-Room Appliances," which will make the book as a whole more useful to students.

NEW YORK TRADE-UNION STATISTICS

Bulletin No. 74, recently issued by the New York State Department of Labor, gives statistics concerning trade unions in the state for the year 1914, with tables comparing the numbers of local unions and members for the several years extending back to 1894. Detailed information is given both at large and by localities. One table groups together stationary engineers and stationary firemen, showing that in 1894 there were in the state 11 local unions with a total membership of 975, as against a membership in 1914 of 11,272, comprising 67 unions. That neither growth in number of unions nor of members has been gradual is evidenced by the fact that the high-water mark in number of unions was reached in 1904, when there were 97, with an aggregate membership of 12,702. The largest enrollment occurred in 1907, when there were 14,574 stationary tending employees affiliated in 74 local organizations in New York. The year 1913 is credited with one more union and 383 more members than 1914. Another table gives data as to engineers and firemen separately by localities and for the years 1913 and 1914. For the latter year, 7,660 engineers in the principal manufacturing centers of the state are shown to have comprised 54 unions, and 3,612 firemen, 13 unions. No city had more than one firemen's union, but the Borough of Manhattan had 14 unions for engineers (4,530 members) and the Borough of Brooklyn seven (1,052 members). To Manhattan 2,800 firemen are credited.

## TRADE CATALOGS

The Stephens-Adamson Manufacturing Co., of Aurora, Ill., has just issued an 84-page bulletin dealing especially with its pivoted-bucket carrier. After a discussion of the classes of service to which this type of carrier is adapted, there are given illustrated descriptions of the carrier, its details and operation. This is followed by reproductions of blueprints and photographs of typical designs and installations, dealing in many cases with interesting details, followed by illustrated descriptions of accessories, like feeders, weighing apparatus, measuring spouts, coal bunkers, gates and valves for coal and ashes and crushers. It is sent free upon application.

## Electric Companies in Japan

According to the monthly report just published by the electricity bureau in the Communications Department at Tokyo, electric enterprises in Japan at the end of May numbered 615, the combined capital amounting to $303,410,786 United States currency. In comparison with the end of 1914 there is an increase of 14 in the number of enterprises and $541,475 in their combined capital.

Power suppliers make up the largest number of these, being 524 in all with a combined capital of $154,793,112, while tram companies number only 44, though their combined capital is $25,520,010. Others number 47 with a combined capital of $123,147,463.

During May four companies were promoted in Hokkaido, Niigata, Nagano, and Ishikawa Prefectures with the object of carrying on lighting operations. The capital called into use for the promotion of these companies is estimated at $62,897.—"Daily Trade and Commerce Reports."